A PROJECTION OF MOTOR FUEL TAX REVENUE AND ANALYSIS OF ALTERNATIVE REVENUE SOURCES IN GEORGIA

A Thesis
Presented to
The Academic Faculty

by

Phillip W. Cherry

In Partial Fulfillment
of the Requirements for the Degree
Master's of Science of Civil Engineering in the
School of Civil and Environmental Engineering

Georgia Institute of Technology
May 2012

A PROJECTION OF MOTOR FUEL TAX REVENUE AND ANALYSIS OF ALTERNATIVE REVENUE SOURCES IN GEORGIA

Approved by:

Dr. Michael D. Meyer, Advisor
School of Civil and Environmental Engineering
Georgia Institute of Technology

Dr. Frank Southworth
School of Civil and Environmental Engineering
Georgia Institute of Technology

Dr. Michael Rodgers
School of Civil and Environmental Engineering
Georgia Institute of Technology

Date Approved: April 1, 2012

ACKNOWLEDGEMENTS

Many people have helped contribute to this effort, most of whom probably do not realize they influenced a fuel tax forecast. This group of family, friends, and mentors has contributed in many ways to my passion for transportation and helping people.

Included in this group of people is my 4th grade my math teacher, Kendell Stone, who helped to show me the benefits of hard work, laying the foundation for many of my future accomplishments. Richard Lines, Dr. LaRell Bissett, other teachers, and the tradition and diversity of Garland High School continued to shape who I am today. Purdue University and its great family atmosphere and professors continued this maturation. I must specifically thank Drs. Jon Fricker and Samuel Labi for their advice and patience as I continually interrupted them in their offices for yet another question.

Dr. Michael Meyer and the other great professors at Georgia Tech, including my thesis committee, sharpened and refined my transportation knowledge and skills. Dr. Meyer's enthusiasm, never-ending energy, and philanthropic nature helps make Georgia Tech a truly enjoyable place to study transportation and provided me with many wonderful opportunities. The programs, classes, and faculty at Georgia Tech make finding a better institute to study transportation a greater challenge than solving Atlanta's traffic problems.

Professionally, I must also give appreciation to Michelle Grondin and HNTB for giving me my first and second internships, which taught me a great deal about the business of civil engineering. Other influential mentors include Paul Grether and Tameka Wimberly of MARTA, who introduced me to the public sector.

My friends also deserve many thanks for their advice and support. Specifically, my current and former roommates, Jeff Wojcicki and Adam and Kelly Van Pelt for their support and tolerance of my many transportation conversations and monologues. I must also thank Jon Coughlin for supporting my interests and his appreciation. Lastly, thank you Lindsay for all of your advice and most of all, thanks pushing me to be my very best in everything I pursue.

Finally, I cannot imagine where I would be without the constant support from my parents. They helped me realize I could do almost anything in this world and have assisted in so many ways over the years. Thanks mom and dad!

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF SYMBOLS AND ABBREVIATIONS

ACS	American Community Survey
ARC	Atlanta Regional Commission
BTS	Bureau of Transportation Statistics
CAFE	Corporate Average Fuel Economy
CDC	Centers for Disease Control and Prevention
CMAP	Chicago Metro Agency for Planning
CNG	Compressed Natural Gas
DOT	Department of Transportation
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EV	Electric Vehicle
FAF	Freight Analysis Framework
FCV	Fuel Cell Vehicle
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GDOT	Georgia Department of Transportation
GHG	Greenhouse Gas
HOT	High Occupancy Toll (lane)
HOV	High Occupancy Vehicle
HPMS	Highway Performance Monitoring System
INDOT	Indiana Department of Transportation
ITS	Intelligent Transportation System

MORPC	Mid-Ohio Regional Planning Commission
MPO	Metropolitan Planning Organization
MSA	Metropolitan Statistical Area
NCHRP	National Cooperative Highway Research Program
NHTS	National Household Travel Survey
NHTSA	National Highway Traffic Safety Administration
NTD	National Transit Database
OBU	On Board Unit
PHEV	Plug-In Hybrid Electric Vehicle
PMT	Person Miles Traveled
PRT	Personal Rapid Transit (vehicle)
REMI	Regional Economic Model Inc.
SRTA	(Georgia) State Road and Tollway Authority
SUV	Sport Utility Vehicle
TIA	Transportation Investment Act
TIP	Transportation Improvement Plan
VIUS	Vehicle In Use Survey
VMT	Vehicle Miles Traveled

SUMMARY

Motor fuel tax revenue currently supplies the majority of funding for transportation agencies at the state and federal level. Georgia uses excise and sales taxes to generate revenue for the Georgia Department of Transportation (GDOT). Inflation and increases in vehicle fuel efficiency have reduced the effectiveness of these taxes in recent years. These changes have resulted in drivers purchasing less fuel and generating less fuel tax revenue, which weakens GDOT's ability to maintain Georgia's transportation assets. This thesis uses literature from regional and state agencies, academic reports, and databases to identify factors that affect motor fuel tax revenue and then creates a model to predict Georgia's fuel tax receipts in 2020 and 2030. It also discusses and evaluates other transportation funding mechanisms that could replace or supplement the fuels tax and recommends how best to implement these strategies.

In Georgia, fuel tax revenue is based on fuel consumption, which is directly affected by vehicle miles traveled (VMT) and fuel efficiency, and fuel price. Several forces influence VMT and fuel efficiency including demographic factors such as population density and persons per household, economic factors such as, income distribution and GDP, and technological factors such as alternative vehicle development. The model incorporates these factors and their interactions by segmenting vehicles into four classes: personal vehicles, single-unit trucks, combination trucks, and transit vehicles, and then creating unique forecasting frameworks for each segment.

The model first calculates 2009 VMT and revenue to compare these projections with known values to validate the model's logic and create a baseline for projecting future revenue. Then, the 2009 model's conceptual framework and additional variables

are used to project future fuel tax revenue. The model calculates revenue from personal vehicles using a proportional categorical method that uses income as its main explanatory variable as well as user-prompted variables in post-processing. Freight revenue is calculated using historical VMT-GDP relationships in combination with other user-prompted inputs.

Because of the model's input-output nature, users can create a virtually limitless array of revenue projection scenarios for 2020 and 2030. To show a probable range of these outputs, conservative and aggressive scenario outputs are presented and discussed for each year. These revenue outputs are compared against the 2009 values on an absolute, per-capita, and per-mile basis. The results indicate that real revenue will increase from 2009 to 2020 but actually decline between 2020 and 2030 due to fuel economy improvements and widespread use of alternatively fueled vehicles.

To counteract these potential revenue declines, this document discusses methods of increasing fuel tax revenue, including increasing the current fuels tax and/or linking it to inflation, VMT-fees, widespread tolling, and regional transportation sales taxes. Each of these mechanisms has advantages and drawbacks, depending on an agency's overall set of objectives. After evaluating each method, the author recommends first evaluating Georgia's upcoming regional transportation sales tax, and then aiming to implement a VMT-fee by 2020 by conducting extensive trials and public involvement. Regardless of what specific steps Georgia's leaders take, change will be needed to maintain Georgia's infrastructure and its economic competitiveness.

CHAPTER 1

INTRODUCTION

1.1 Research Background & Motivation

Motor fuels taxes are currently the major funding source for transportation agencies at both the federal and state levels. These taxes are levied on a per-gallon basis (excise taxes), as a sales tax, or as a combination of both. Georgia's state motor fuels tax incorporates both of these collection methods, with a 7.5¢/gallon excise tax rate and a 3% sales tax on wholesale fuel. An additional 1% sales tax is levied on the sale of motor fuels toward Georgia's general fund (1). Figure 1 illustrates motor fuels tax collection in Georgia.

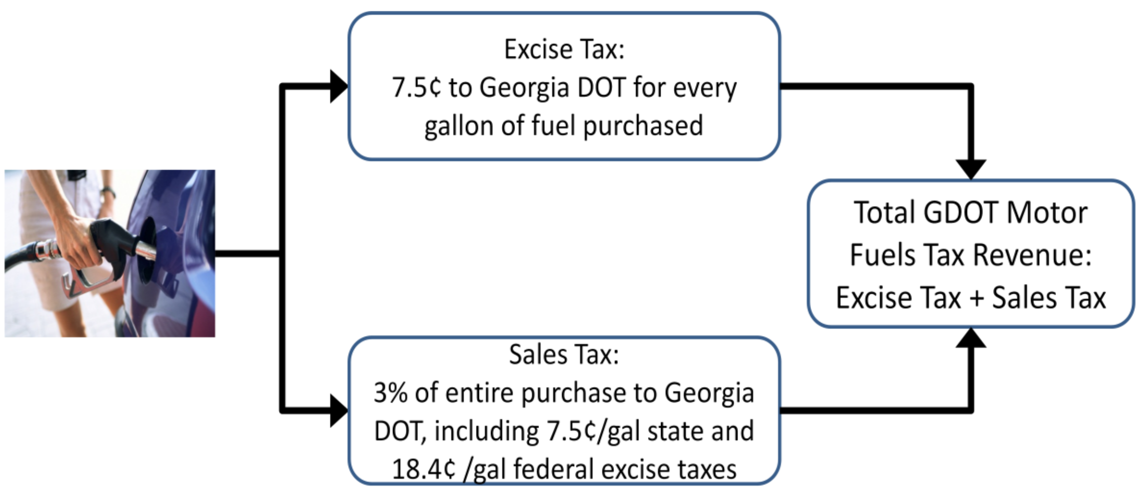


Figure 1: Georgia Motor Fuels Tax Collection

From a transportation agency's perspective, it is important to identify those factors that affect motor fuel tax revenue in order to budget for future transportation maintenance and rehabilitation projects. Figure 2, for example, illustrates how vehicle miles traveled (VMT), vehicle fuel economy, and the prevailing fuel price can affect the magnitude of fuel tax revenue.

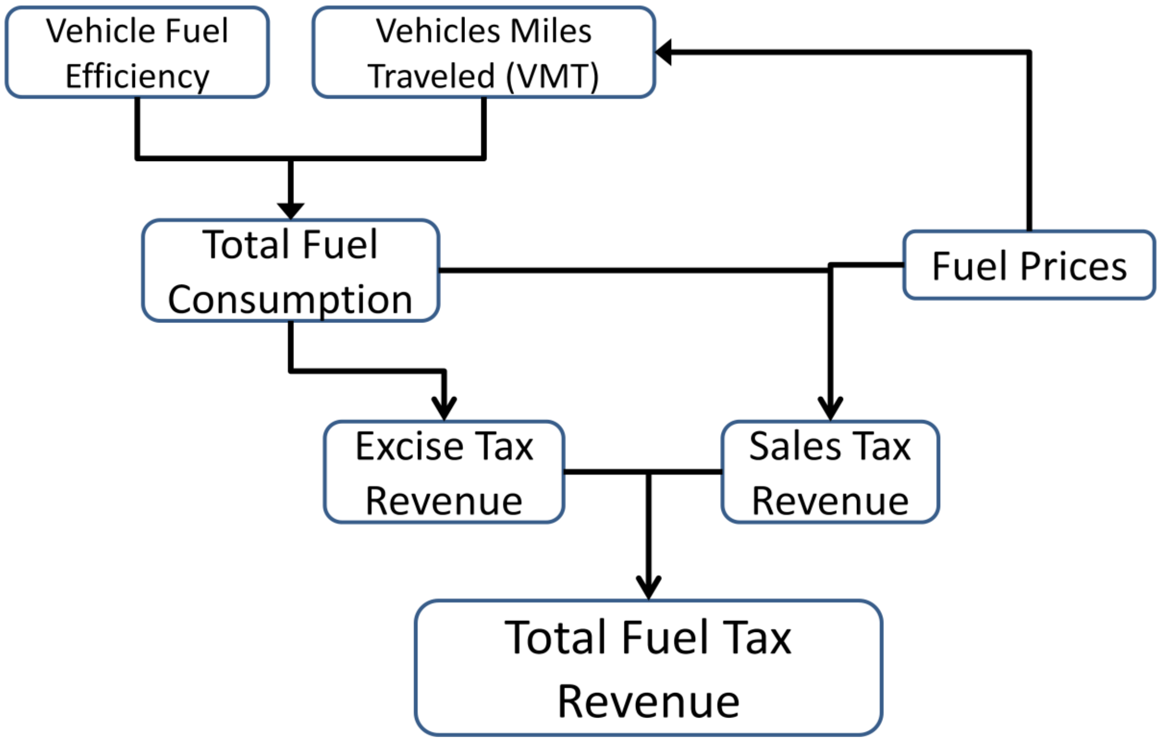


Figure 2: Factors Affecting Fuel Tax Revenue

This budgetary and allocation process has major safety implications throughout the nation where many bridges and other assets are approaching or have exceeded their design lives.

Fuel prices drive fuel tax revenue in two ways: the amount generated from the sales tax and the impact on overall demand via elasticity. Thus, rising fuel prices increase sales tax revenue for the agency on a per-gallon basis, but decrease the number of gallons purchased due to fuel-price elasticity, as consumers respond to increasing prices in the short term by purchasing less gasoline. Figure 2 also indicates that increasing VMT leads to increasing fuel tax revenue, as more miles driven equates to more gallons of fuel purchased, and indicates that increasing vehicle fuel economy leads to decreasing revenue, because vehicles can travel the same distance on less fuel.

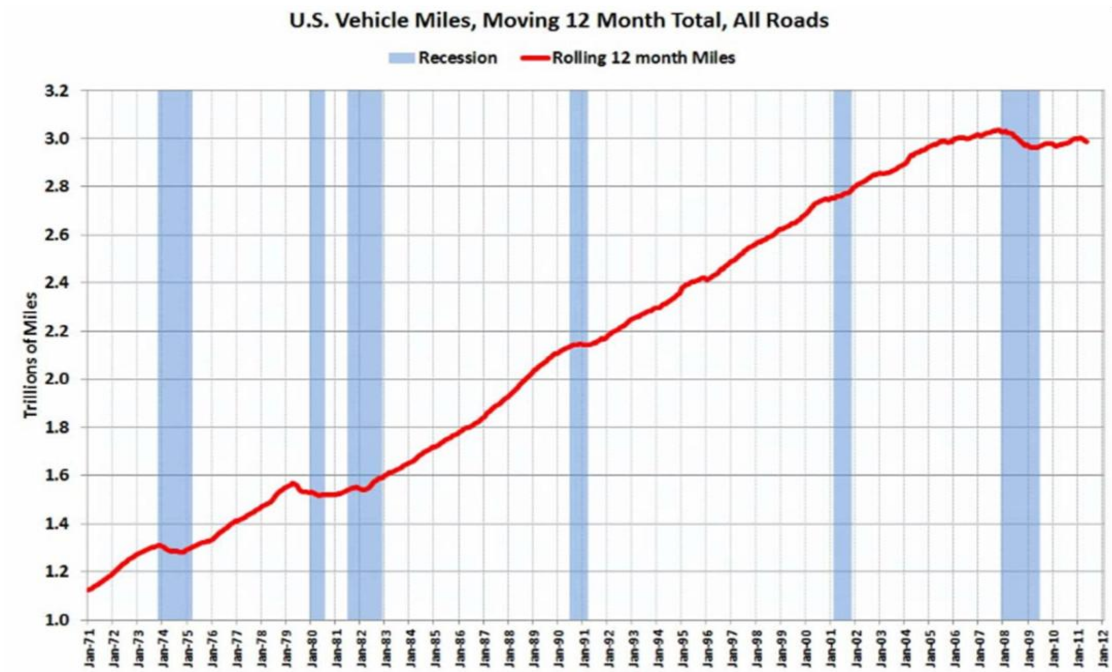


Figure 3: Historical U.S. VMT Trend from 1971-2011 with Associated Economic Recessions (68)

Figure 3 shows historical VMT trends from 1971 to mid 2011. As shown, aggregate yearly VMT increased nearly monotonically from 1971 to 2008; however, the figure also shows that the economy influences VMT, as VMT stagnated or decreased during every recessionary period during the past 40 years. In terms of travel behavior, it is also important to note that nationwide VMT growth began stagnating in 2005 well ahead of the most economic recession that began around 2008. Understanding why VMT growth has slowed, and if this pattern will continue, is important in projecting fuel tax revenue in Georgia.

Fuel economy is the second component that influences the amount of fuel consumed at both the individual and aggregate levels. Until fuel prices reached those seen in 2008, fuel economy had remained largely unchanged for many years and had received little push from either manufacturers or consumers. In conjunction with this, the Corporate Average Fuel Economy (CAFE) standards for passenger cars remained at 27.5

mpg from 1992 to 2010, and the CAFE standard for light duty vehicles remained constant at 20.7 mpg from 1996 to 2004 (2). However, manufacturers, consumers, and the government have all responded to higher fuel prices in recent years. The market has responded to consumers demands for more fuel-efficient vehicles by creating new vehicles technologies such as improved hybrid, and plug-in hybrid electric vehicles (PHEVs). These new technologies now even apply to sport-utility vehicles (SUVs), and luxury vehicles. The Chevrolet Volt and Nissan Leaf are two vehicles that illustrate these new technologies. The federal government has increased the CAFE standards for future years, with a 35.5 mpg standard in place for 2016 and a 54.5 mpg standard for 2025 that has been published for public comment (2). Such fuel economy mandates would drastically improve the fuel economy of the nation's and Georgia's new vehicles, while also providing environmental and energy security benefits. Future research is ongoing to develop other vehicle technologies such as hydrogen fuel cell vehicles (FCV) that would also further reduce per-capita gasoline consumption (3).

Reduced growth in VMT and rapidly increasing fuel economy could have significant impacts on fuel consumption and thus fuel tax revenue. Under the current fuel tax structure, as more alternative fueled vehicles enter the nation's fleet, Georgians will consistently generate less per-mile fuel tax revenue. Agencies must understand long-term VMT and fuel economy trends and the effect of these trends on providing the necessary funds for system maintenance and where necessary, capacity expansion.

1.2 Study Overview

This thesis identifies those factors that affect highway revenues in the state of Georgia, produces a conceptual framework depicting how the key factors that influence highway revenues are interrelated, and develops a model that projects future motor fuel tax revenue in Georgia in 2020 and 2030. The model is designed to be an input-output tool that allows the model user to quickly and easily change the values of model inputs to observe how changes to the different input factors result in various revenues. The user can use the model and its results to understand which factors will significantly affect future motor fuel tax revenue. In addition to the motor fuel tax revenue projections, this study also examines other transportation revenue mechanisms that could replace or supplement the motor fuel tax in Georgia, and the implementation strategies and barriers associated with each mechanism. This research offers a long-range budgetary planning aid to help policymakers understand how external factors may affect transportation revenue in the coming decades, and to provide alternatives to the current funding methodology to help ensure that transportation agencies have the funds necessary to maintain and expand their transportation assets.

CHAPTER 2

LITERATURE REVIEW

This review is prior work in this area organized by source, including Metropolitan Planning Organization (MPO) and state Department of Transportation (DOT) plans, government and academic publications, futurist projections, databases, and Georgia DOT (GDOT) brochures and reports. The sources describe factors that will affect future VMT, future fuel economy and vehicle technologies, they discuss past examples of motor fuel tax projections, and analyze the potential of alternative transportation funding mechanisms. The geographic and source variety of literature helped to ensure that the study incorporated ideas from across the national transportation spectrum. The literature review covers the following sources:

- MPO Regional Transportation Plans
- Statewide Transportation Plans
- REMI Output
- Government Reports
- Academic Publications
- Futurist Books
- Databases

2.1 MPO Regional Transportation Plans

Regional Transportation plans offer insight into how transportation and planning experts and government officials view the future of transportation related issues such as population growth, job growth, and transportation system expansion at the regional level. The federal government mandates that every MPO produce a regional transportation plan and that it clearly identifies a metropolitan region's transportation strategic plan for the next two to three decades. These regional plans are then coordinated with a region's Transportation Improvement Program (TIP), which identifies particular transportation projects that regional agencies will implement in a 3-5 year horizon.

This literature review centers on the strategies listed in the Atlanta Regional Commission's (ARC) 2030 and 2040 regional transportation plans, while also surveying trends and objectives of other cities' regional transportation plans. Although the particular attributes and data of other regions' transportation plans, such as population growth, are not directly relevant to Georgia, the objectives presented in these other plans indicate policy measures that Georgia might consider adopting in coming decades.

Because most regional transportation plans are similar in structure, this review of non-Georgia regional transportation plans will discuss only the content that is unique and relevant to the objective of identifying factors that influence motor fuel tax revenue via either VMT or fuel economy.

2.1.1 Atlanta ARC 2030 Regional Plan

Atlanta's 2030 Regional Plan was adopted in its final form in September of 2007. The 2030 plan discusses how the region would conform to the planning requirements stipulated by the then recently passed SAFETEA-LU federal legislation and how the authorization affected the region's goals. Figure 4 shows the plan's projected spending distribution over the next 25 years, and that the majority of priority area funding would be spent updating and optimizing current transportation assets.

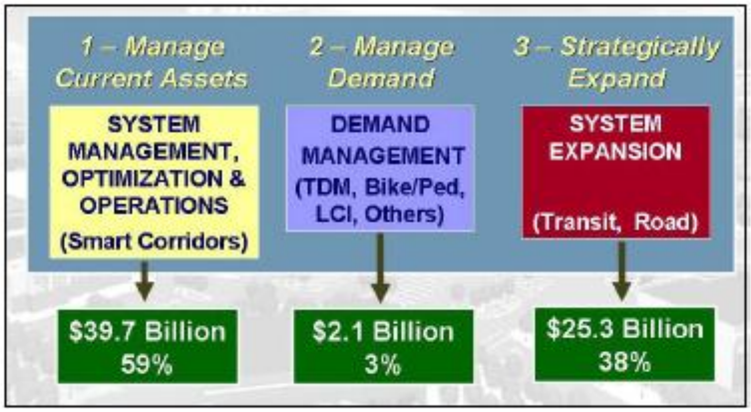
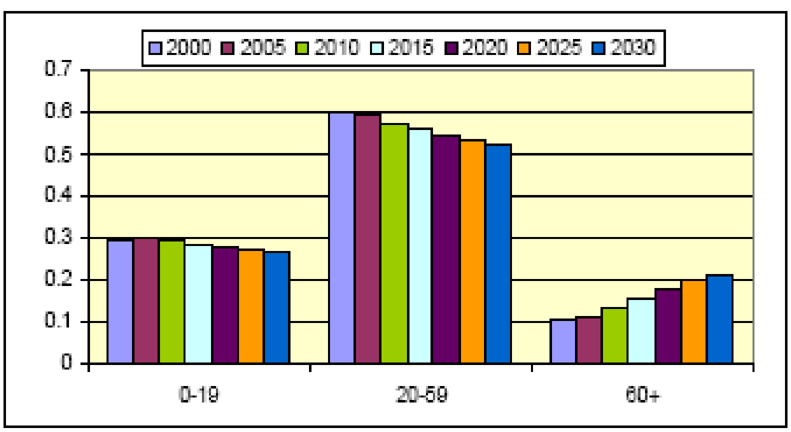


Figure 4: ARC 2030 Regional Plan Priority Areas (4)

The 2030 plan highlights the Atlanta region's rapid growth, as the Atlanta metropolitan area lead the nation in absolute population growth from April 2000 - July 2006 (4). The plan stresses how this growth has strained the region's transportation system and how congestion will continue to increase if similar population growth continues. The plan projects a 2030 regional population of just under 7 million residents, adding approximately 91,000 persons per year during this period (4). Within this projection, the plan also projects an increasing percentage of individuals in the 60+ age cohort, as shown in Figure 5.



Source: ARC, 2006

Figure 5: Historical and Projected Age Distribution in Atlanta Region (4)

The 2030 plan references an ARC *Needs Assessment Report*, which states that interstates in the Atlanta region are reaching their carrying capacity (4). This conclusion, in combination with the high costs and difficulties associated with adding new highway capacity, prompted the region to pursue a multi-modal strategy to optimize the existing network. Figure 6 represents the projected increase in travel time based on increases in congestion in 2030 versus 2005.

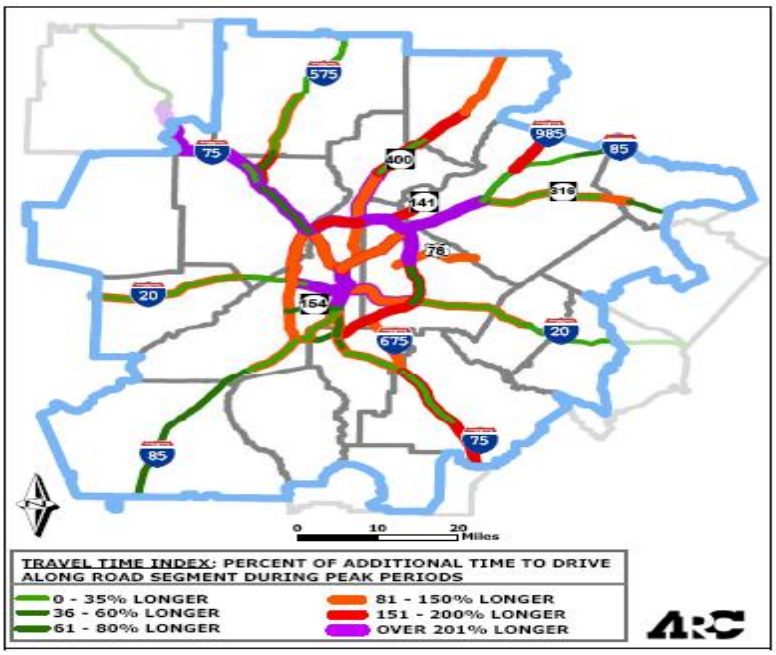


Figure 6: Projected Travel Time Increases in the Atlanta Region (2030) (4)

The 2030 plan also briefly mentions the region's plans for expanded transit, bicycle, and pedestrian facilities in order to improve accessibility for those who cannot or do not want to drive and to mitigate future congestion increases.

The plan recognizes the current as well as future congestion problems that face the region; however, it is limited in how it addresses solving these issues, relying mainly on building additional roadway capacity.

2.1.2 Atlanta (ARC) 2040 Regional Transportation Plan

The 2040 Regional Transportation plan, completed on June 22, 2011, in its draft form, offers a more current analysis of Atlanta's transportation needs than the 2030 plan described in section 2.1.1. In addition to updated demographic data, it also more comprehensively treats the issue of sustainability, and offers more solutions to Atlanta's transportation issues, such as a more detailed bicycle, pedestrian, transit expansion program, and alternative funding strategies like High Occupancy Toll (HOT) lanes.

The 2040 plan mentions the following as reasons for the Atlanta region's recent population growth: national migration to the Sunbelt, inexpensive land, federal funding programs that support decentralized growth, access to Hartsfield-Jackson airport, low cost of living, and proximity to Fortune 500 companies, premier universities, and the Centers for Disease Control and Prevention (CDC) (5). Figure 7 illustrates that ARC expects the region's population to exceed 8 million people in 2040, with the majority of the growth occurring in Fulton and Gwinnett counties.

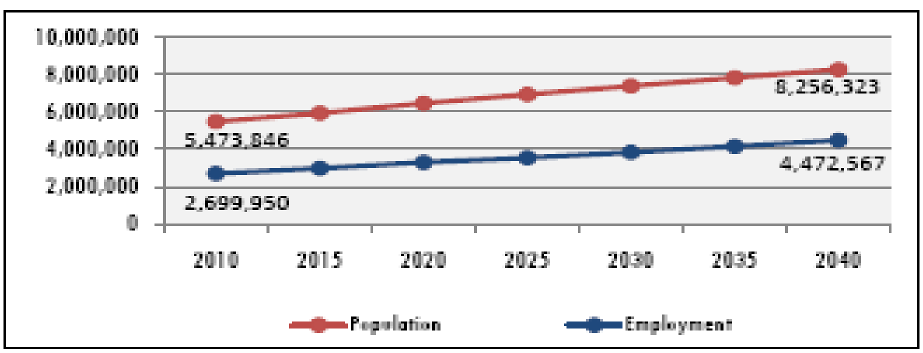


Figure 7: Projected Atlanta-region Population Growth through 2040 (5)

The 2040 plan states that significant growth will also occur in the ten counties that fall within the 20-county non-attainment region but outside of the 10-county MPO. This growth implies growth in the region's exurbs, possibly resulting in longer commuting trips. Many of these counties are currently predominantly rural but are likely to become more urbanized as the Atlanta region's population growth forces additional land consumption. This increase in land development is likely to change travel patterns in these areas as well as strain infrastructure, as the roads in these areas were not designed for high traffic volumes.

In addition, the 2040 plan updates the region's forecast congestion and the effect of this congestion on the local economy. Figure 8 illustrates the impact of this congestion on regional travel times, and it shows that area residents will have to dedicate more time to travel and commuting if no improvements are made.

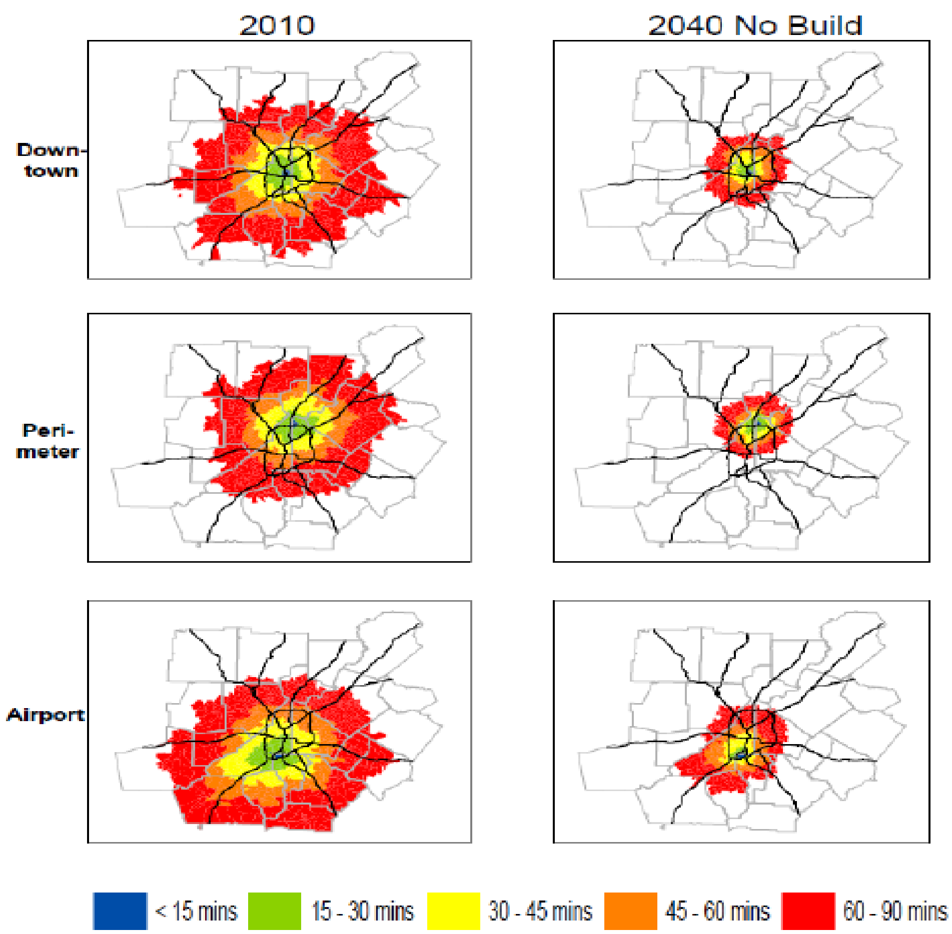


Figure 8: Impact of Congestion on Regional Travel Times in 2010 and 2040 (ARC 2040 Regional Transportation Plan) (5)

As was also mentioned in the 2030 plan, the 2040 plan predicts that a greater percentage of the region's residents will fall in the 60+ age bracket and explains how this demographic transition will result in additional special mobility and para-transit needs (5).

In addition, increasing fuel costs will constrain individuals' housing choices, as these final costs represent an increasingly higher percentage of household budgets. The plan also states that inexpensive suburban land and fuel costs have helped drive the area's population growth, but that increasing fuel prices could stifle this growth, as more distant inexpensive land translates to costly commutes.

The 2040 plan includes steps to combat congestion and increasing fuel costs as well as improve the quality of life for its residents. These steps include ideas such as greater accessibility to community resources via improved pedestrian facilities and more extensive bike routes with increased connectivity. The plan also recommends new zoning requirements in the form of minimum development and population densities. The plan also mentions implementing a State of Good Repair initiative to ensure that transit and road facilities are maintained, improved transit connectivity between housing and jobs, improved energy efficiency of transit vehicles, and establishing a regional economic growth strategy to re-invest in the region's transportation infrastructure (5).

Finally, the plan mentions alternative roadway optimization mechanisms such as the newly implemented I-85 HOT lanes and other travel demand techniques, new forms (to the Atlanta region) of transit, such as streetcars and light-rail technology, and identifies specific interchanges throughout the region that could be redesigned to alleviate congestion (5).

The ARC 2040 Regional Transportation Plan is useful to the present study in that it identifies ARC's most recently stated regional transportation goals and strategic steps planned to achieve these goals. One must understand these goals and how they affect VMT and fuel economy when one creates a model to project these values.

2.1.3 Columbus, Ohio 2030 (MORPC) Regional Transportation Plan

Adopted in 2008, the 2030 Columbus transportation plan is similar in content and layout to ARC's 2030 and 2040 regional plans, albeit with data specific to central Ohio. However, the Columbus plan differs from the ARC plans discussed in sections 2.1.1 and 2.1.2 in that it more explicitly states an objective to reduce regional VMT. In support of reducing VMT, the Columbus 2030 plan emphasizes sustainable transportation projects such as Complete Streets, which aim to encourage walking and biking and can help to promote higher population densities (6). In conjunction with the Complete Streets concept, the Columbus plan re-evaluates walking behavior and outlines a strategy to incorporate pedestrian behavior into transportation system expansion.

2.1.4 Chicago, Illinois (CMAP) 2030 Regional Transportation Plan

The Chicago Metropolitan Agency for Planning approved the finalized version of Chicago's 2030 Regional Transportation Plan in October of 2008. The plan provides explicit goals and the policy strategies for achieving these goals. Both ARC's 2030 and 2040 plans, and Chicago's 2030 plan mention strategies such as increased walking, biking, and transit usage, real time travel information, and maintenance programs (7). However, Chicago's 2030 plan includes other directives not mentioned within ARC's plans. These include encouraging redevelopment and infilling unused land, aggressive parking pricing, locally planned land-use patterns, location-efficient mortgages, and balanced zoning throughout the region to optimize overall travel patterns (7).

Although Chicago's earlier development and dense land use resulted in a more transit-friendly environment than is seen in Atlanta, it is plausible that Atlanta could employ redevelopment and infill strategies and encourage more diverse land use. Such initiatives would likely reduce VMT and affect fuel tax revenue in Georgia.

2.1.5 Minneapolis, Minnesota (Metropolitan Council) 2030 Transportation Policy Plan

The Minneapolis 2030 Transportation Policy Plan was adopted in November of 2010. It contains many of the same strategies listed by the Atlanta, Columbus, and Chicago MPOs in their transportation plans, which include neighborhood level zoning and planning, detailed bike/pedestrian and transit planning, more advanced pricing schemes for parking, better job accessibility to transit and housing, and congestion mitigation and travel demand management programs (8). The Minneapolis plan differs from the previous transportation plans by more aggressively encouraging carpooling and vanpooling, advancing the preservation of future transit corridors, and promoting transit oriented development housing with a range of prices (8).

From the initiatives outlined in their 2030 plan, the Metropolitan Council's transportation objectives are also likely to reduce VMT via a variety of measures, and the plan presents many explicit means of achieving such a reduction. Many of these means correspond to similar ongoing transportation projects or plans in the Atlanta region, such as the Beltline and the Transportation Investment Act (TIA). These projects aim to preserve transit corridors, expand transit service, and incorporate technology to optimize and maintain Atlanta's existing transportation network.

2.1.6 2.1.6 Portland (METRO) 2035 Regional Plan

Metro, Portland's MPO, adopted the 2035 Regional Transportation Plan in June of 2010. Metro and the Portland region have a reputation for being a progressive transportation area, due to its regional growth boundary and other innovative planning measures. It also has an extensive bike-lane network, a light rail and integrated streetcar transit network, and has highly integrated pedestrian access. Because of this, the growth of per capita VMT has stagnated in the region, such that it is now 20% of that of comparably sized metro regions in the nation (9). In conjunction with this reduction, one of the 2035 plan's explicit objectives is to "reduce vehicle miles of travel."

In defining performance objectives, Portland outlines volume to capacity guidelines and performance measures for different road types or regions. Portland also sets mode share goals for different subregions as part of reducing drive-alone mode share and increasing biking, walking, and transit shares (9).

Portland's 2035 plan also notes that the region will attempt to respond to climate change in future plans. Because mobile-source emissions contribute greatly to climate change, this statement implies a desire to further reduce VMT.

Many of the other regional transportation plans surveyed for this research list the strategies that Portland has employed during the past few decades; however, few U.S. cities have as much experience actually implementing these strategies as Portland. The policies implemented in Portland over the past few decades evidence that these strategies can result in significant VMT reductions and thus reduced motor fuel tax revenue. When examined holistically, Portland's transportation planning policies are more innovative and far-reaching than those of almost any other region in the country. Metro's ability to enact such legislation is based partly on Oregon's state government granting them the power to do so. Thus, many legislative changes would need to occur for ARC and other Georgia MPOs to attempt to enact the policies seen in Metro. However, the model described in Chapters 3 and 4 of this thesis will attempt to incorporate inputs to allow for the affects of such legislative changes in the future.

2.2 State Transportation Plans

Statewide transportation plans are similar to the regional transportation plans surveyed in section 2.1, although they approach transportation issues and solutions from a broader geographic perspective. Also, because state DOTs own infrastructure assets and MPOs generally do not, statewide transportation plans dedicate more attention to the condition of the bridges, roads, and other assets within a state. In particular, statewide plans can significantly influence travel behavior via investments and legislation. Because of this, reviewing statewide transportation plans is important when projecting future travel behavior and ultimately, motor fuel tax revenue.

2.2.1 Georgia 2035 Statewide Transportation Plan

The Georgia 2035 transportation plan was finalized in January of 2006. While the plan was finalized in early 2006, and therefore does not account for the events of the past six years, including the high and volatile fuel prices seen since 2008, the continued economic recession, and the accompanying high rates of unemployment, it still includes many transportation policies, plans and projections, specifically relevant to multi-year travel trends in Georgia.

One of the strongest VMT indicators for a given area is projected absolute population growth. Figure 9 illustrates the 2035 plan's projected population growth by region within Georgia. It is important to notice that the statewide plan projects the Atlanta region to have the highest absolute and percentage growth rate (10).

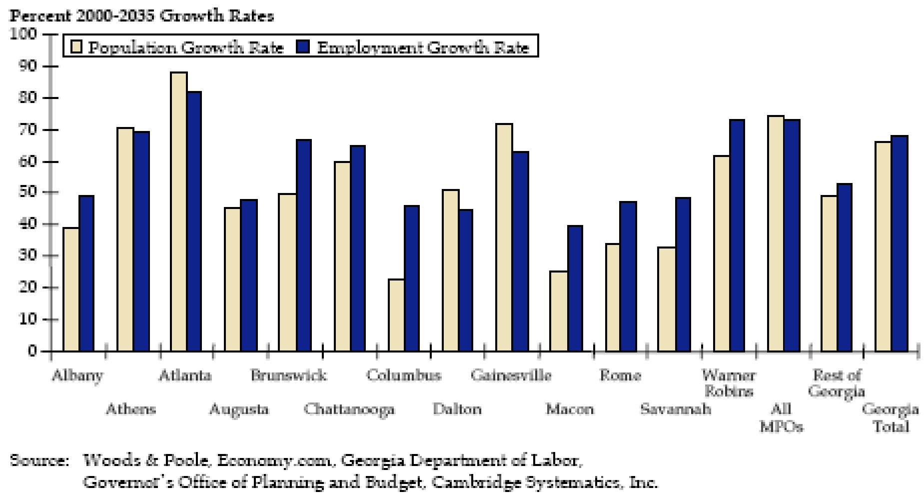


Figure 9: Projected Population Growth (10)

The Georgia statewide plan identifies the following factors that could affect future economic growth: military spending, global recession, increasing fuel prices, outsourcing, and the increasing age of baby boomers (10). Many of these factors have already influenced the Georgia economy in the past six years since the report's publication, as there has been a recession, fuel prices have increased, outsourcing has occurred, and the baby boomer generation has entered the 60+ age cohort. Based on current federal legislation, it is also now likely that military spending will decrease, which will affect Georgia's population and economy through both the closure of military bases and decreased employment at defense contractors like Lockheed Martin. Georgia's future economic climate affects both personal and freight VMT, as the economy impacts employment and population decisions as well as the movement of goods.

Despite the recent economic downturn, if one assumes the plan's projected population growth projections to be reasonable, then it is expected that the state's roads will become more congested. Figure 10 shows the predicted decline in the level of service of the state's roads by region under build and no-build scenarios. From the figure one can see that the state expects significant increases in congestion by 2035, regardless of any realistic service capacity increases.

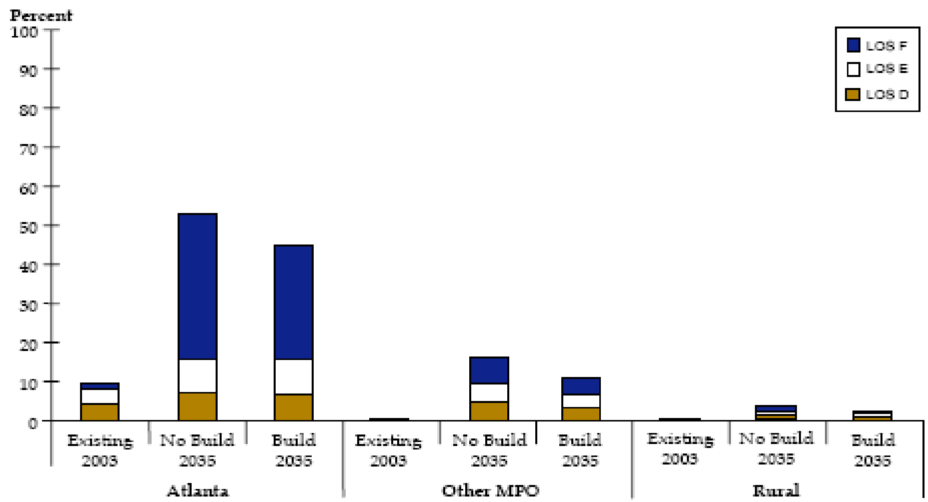


Figure 10: Projected Level of Service in Georgia under Build and No Build Scenarios (10)

Also contributing to deteriorating level of service is increased freight traffic. The 2035 plan predicts that freight traffic (in ton-miles) will increase 171 percent from 2005 to 2035, and that the mode-share of freight by truck will also increase (10). This means that there will be significantly more trucks on Georgia's roads in coming years. This growth in truck traffic will influence GDOT's highway maintenance budget via both expenditures and received revenue. Freight trucks damage pavements much more than passenger vehicles, and trucks have the potential to generate additional revenue via weight-distance and other funding mechanisms.

The 2035 plan also projects future fuel tax revenue. It states that in 2005 the plan projected an expected annual growth rate of 1.33% (10); however, the volatile revenues of the past six years have thus far proven such predictions incorrect.

Because the 2035 Georgia statewide plan is over six years old, many of its predictions and data may prove to be out of date due to recent economic events. However, the plan's broad population and congestion projections retain relevance.

2.2.2 California 2025 Statewide Transportation Plan

The California 2025 Statewide Transportation Plan addresses many of the same issues as Georgia's statewide plan discussed in section 2.2.1, including the condition of existing infrastructure, population growth, changes in demographics, and projected congestion, albeit specific to California. However, California's statewide plan does devote more attention to technology and its potential impacts when compared to Georgia's statewide plan.

California is at the forefront of transportation technology in the United States, due in part to Silicon Valley's technical expertise, and the need for innovation that stems from the high levels of congestion and the mobile source emissions prevalent in southern California and in the Bay Area. Technology may change the way people drive via new vehicle types such as plug-in hybrid, electric, and/or fuel-cell vehicles. It may also change the way vehicles interact, using sensors and short-range communication to detect other vehicles and obstacles, resulting in safety improvements. In addition, it may change how frequently people drive, perhaps substituting telecommunication and of online, internet ordering.

California's state transportation plan also discusses land use patterns and the housing-employment mismatch that occurs when there is a shortage of available affordable housing (11). In California, this mismatch occurs in the San Francisco and Los Angeles metropolitan areas, resulting in longer commutes and increased congestion in regions that already see some of the highest congestion in the country (11).

The technological advances discussed in California's state transportation plan provide considerable food for thought. Modern technology evolves rapidly, and predicting the vehicular and wayside innovations that manufacturers will implement in the next ten to twenty years is difficult. For the purposes of this report, it is important to understand how implementing these technologies could affect VMT, fuel economy, and fuel tax revenue.

2.2.3 Texas 2035 Statewide Transportation Plan

The 2035 Texas statewide transportation plan was completed in 2010 and addresses many of the same concerns that Georgia and California presented in their statewide plans. Some of the factors that the Texas 2035 statewide plan mentions that influence travel demand are population growth, age distribution, employment trends, disposable income, economic disruptions, transportation network capacity, and major employment relocations (12). In addition to these variables, the plan also takes an in-depth look at several broader topics that could change the landscape of transportation in Texas.

The first topic listed is energy resources, and this section discusses how changes in these resources affect travel behavior. The plan states that both residents and transportation officials need to consider the impact of increasing fuel prices, alternative vehicles on infrastructure and potential alternatives to the motor fuel tax. The statewide plan predicts that if household costs for transportation can remain stable by using alternative fuels, that overall transportation demand will likely increase due to population increases; however, it also predicts that if costs either increase or are unstable, that travel demand could decrease (12). Because fuel supply is global, these fluctuations are just as likely to occur within Georgia and could have the same impact on travel patterns.

The second topic is climate change. The plan mentions that increasing temperatures could bring a rise in sea level and more extreme events such as hurricanes and floods (12). These extreme events could disrupt coastal activity such as flights, seaports, and rail movement, and coastal roads. Increased hurricane frequency could also result in more evacuations, requiring more disaster-relief revenue and resulting in fewer miles driven within a disrupted economy. Intense heat could also weaken pavements more rapidly, resulting in more construction costs and travel delays.

The third topic in the Texas 2035 Plan is urban livability and sustainable living. The plan discusses how downtown revivals, inner-city development and infill, expanded transit systems, and an increased desire for biking and walking options could make Texas less auto-centric and reduce per-capita VMT (12). Some regions, such as Atlanta, have already incorporated these objectives, as evidenced by ARC’s 2040 plan described in section 2.1.2.

The fourth topic is changing personal travel behavior. This includes travel demand management and congestion management measures such as HOV lanes, carpooling, telecommuting, and modified parking standards to increase parking costs and encourage transit use (12). Such measures are already in place in the Atlanta region and are mentioned in ARC's 2040 regional transportation plan and seen on I-85 in the form of HOT lanes.

The fifth and final topic is vehicle technology. As was mentioned in California's 2025 statewide transportation plan in section 2.2.2, this technology includes such advancements as intelligent transportation systems (ITS), GPS, improved traffic signal timings, and other travel demand management measures that could reduce congestion and increase capacity. Agencies and jurisdictions within Georgia are also likely to adopt some of these technologies, resulting in similar transportation effects.

In addition to the five aforementioned factors, the Texas 2035 Statewide Plan also lists the forces affecting VMT growth in Texas. These forces are population growth, commercial freight, the quantity of travel per person, international imports and exports, and how much tourist and business opportunities expand in Texas (12). Many of these factors are also relevant to Georgia and could affect travel behavior.

The Texas 2035 statewide transportation plan provides a holistic yet comprehensive analysis of which factors will affect transportation in Texas in coming years. Most of these topics and their implications are also relevant to Georgia and should be considered when assessing future VMT and fuel tax revenue.

2.3 Atlanta Regional Commission REMI Output

Regional Economic Modeling Inc. (REMI) has developed a forecasting tool that projects variables such as population, migration, and employment. The ARC uses this software package to project demographic and economic data several decades into the future. The model projects demographic information by age, race, and location within Georgia, and projects economic data by service sector. In addition, the REMI software projects these outputs for the ten-county metro region, the twenty-county non-attainment region, all other counties in Georgia, and the entire state (13).

Figure 11 shows the projected statewide growth by age cohort. One should notice the relatively rapid increase in the 65+ age cohort as compared to the other age groups listed.

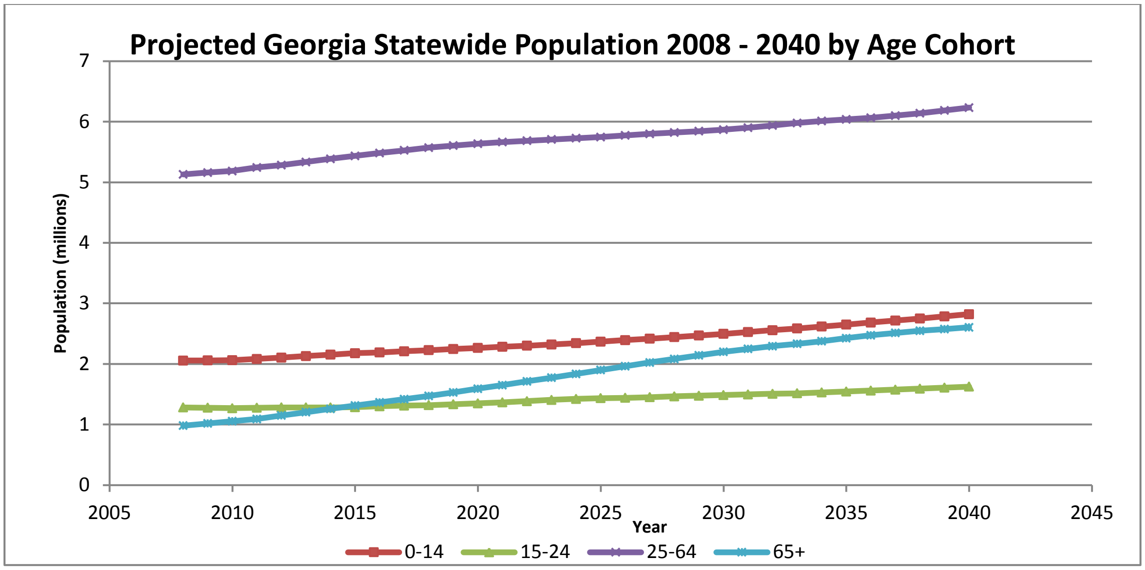


Figure 11: Projected Statewide Population Growth by Age Cohort (13)

Figure 12 shows the projected geographic breakdown in projected population. In the figure, “core counties” represents Fulton, DeKalb, Gwinnett, Cobb, and Clayton, Henry, Rockdale, Douglas, Fayette, and Cherokee counties; the surrounding counties represents the other ten counties in the Atlanta non-attainment area. As can be seen from the figure, the REMI model projects the core and surrounding counties of Atlanta to grow faster than the other counties in the state; however, the model projects the entire state’s population to grow (13).

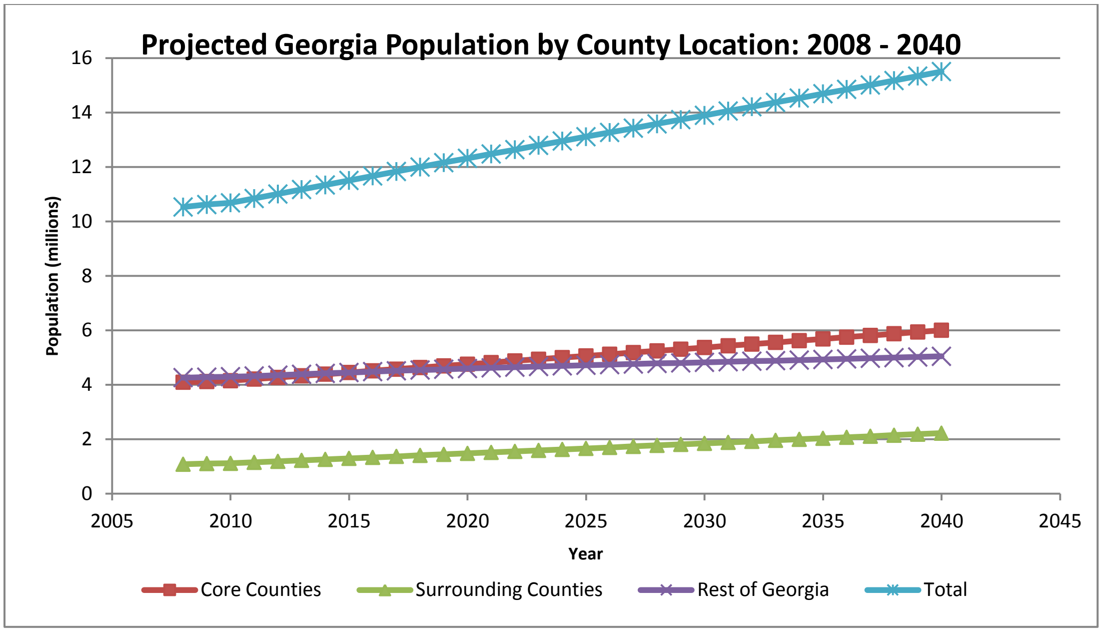


Figure 12: Projected population in Georgia by County from 2008 - 2040 (13)

Economic activity is also highly correlated to travel behavior. Figure 13 on the following page illustrates the economic output of the REMI model. It shows projected Gross Domestic Product (GDP) in billions of dollars along with projected employment in thousands of persons. The projection shows a steady increase in employment along with a more gradual increase GDP (13).

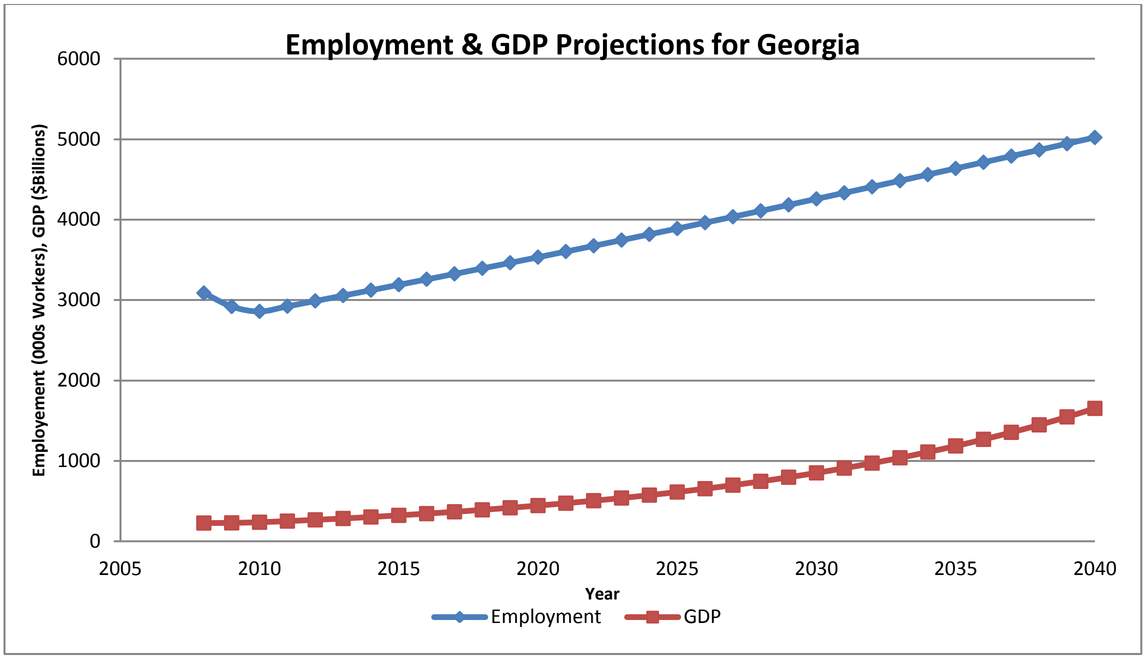


Figure 13: Projected Employment and GDP for Georgia 2008-2040 (13)

The outputs from the REMI software are recent, specific to Georgia, and project many different variables within each sector. Because of this, the revenue projection model in this thesis uses these outputs extensively, as will be seen in chapters 3 and 4.

2.4 Government Reports

The following reports represent federal level analyses of transportation trends, issues, and data relevant to this research. Federal policies can impact state policy, and thus surveying federal reports is helpful in understanding states' possible future actions.

2.4.1 NCHRP Project 20-80 Task 2: Long Range Strategic Issues Facing the Transportation Industry

ICF International authored this report and completed it in October of 2008. As with the Texas statewide transportation plan in section 2.2.3, the report describes a framework for identifying future trends and problem areas to better prepare the transportation sector for changes and better shape its transportation future (14). In creating this framework, the report committee assumed a 50-year time horizon and looked beyond those issues currently facing the transportation industry. After its completion, the resultant framework contained five key forces that encompass various factors and trends.

The first of these forces centers on government and politics. This section discusses how changing transportation financing mechanisms would affect the financial capacity to construct and maintain transportation assets. It also analyzes how the possibility of terrorist acts can affect the design, implementation, and cost of transportation infrastructure (14).

The second force is economics, and in particular, economic activity that drives transportation, whether through the delivery of freight goods or personal travel. The report emphasizes that it is important that transportation efficiency remain constant, or improve, to ensure travel times do not escalate as the population increases. In addition, because the world's economy is now so interactive, development in foreign markets like China and India can change the volume of transportation routes within the United States, increasing the impetus for efficient movement of goods (14).

The third force in the NCHRP report discusses demographics and societal choices. Population growth, migration, the growth of certain age cohorts, and urban development patterns will all affect travel behavior and VMT in coming years (14). The aging of the baby boomer generation will cause the percentage of elderly to grow rapidly during the coming decades, which could result in a significant number of people transitioning to a part-time employment, or "soft-retirement", with different travel behavior than either full-time employees or stay at home individuals (14). Evidence also suggests that young people may not enter the work force as quickly in coming decades, choosing instead to travel or do volunteer work immediately after their schooling ends. As people marry later, changes in family structure are also likely to occur, with fewer married couples living together and lower birthrates (14).

Environmental and Energy constraints is the fourth force discussed that could affect travel. Increased competition for natural resources and increasing fossil fuel prices could later force society to use alternate sources of fuel for vehicle propulsion. In addition, emission-induced climate change could also prompt stricter emissions regulations, resulting in alternative transportation forms or travel restrictions (14).

The fifth and final force is technology. Technology could induce many changes across the transportation landscape, including medical advancements, computing, and vehicle technology. Medical advancements could dramatically extend lifespan, resulting in increased populations and greater VMT. Computing advancements could make it easier to telecommute via the internet and within company intranets (14). Vehicle technology could advance alternative fuels to help the environment and could improve vehicle-to-vehicle and vehicle-to-wayside communications to increase vehicle safety and reduce transportation fatalities (14).

Each of these forces could have a significant impact on VMT in Georgia. While some of the demographic and governmental factors are specific to Georgia, federal transportation policies can have major impacts on transportation in Georgia. Technology advancements, economic swings, and environmental constraints could also all affect the travel behavior of residents in Georgia and consequently, the motor fuel tax revenue GDOT receives.

2.4.2 NCHRP 20-83A Long-Range Strategic Issues Facing the Transportation Industry Workshop

This workshop is a follow-up to the report detailed in section 2.4.1 and featured many different guest speakers across many industries. The workshop was organized to include input from experts to consider the transportation impacts resulting from factors such as demographic shifts, fuel shortages and alternative fuels, climate change and environmental concerns, new funding mechanisms, public-private-partnerships, and a possible shift from a global to a more local economy. The workshop was valuable because it incorporated input from experts outside of the transportation field, which established a broader scope and assisted in establishing which non-transportation developments are feasible.

Several of the speakers discussed how medical advancements would prolong life and keep humans functioning at higher levels for longer periods. These advancements stem from the human genome project, the role of genetics in treating cancer, and healthier people through the process of genetic selection (15). The participants then discussed the fact that even with longer life spans, as the baby boomer generation ages, many may move closer to transit or para-transit friendly destinations (15). Thus, longer life spans may not result in significantly increased VMT.

Another area of focus at the workshop was technology. Some of the specific examples are a "personal brain" that can remember appointments and where one needs to be at all times, akin to the newest Apple iPhone's Siri technology (15). This device or similar devices could reduce VMT by optimizing travel patterns and routes. Another technology discussed is nanotechnology. Nanotechnology could improve many materials, such as pavements and by making them last longer and reducing the need for construction and assorted delays (15). The workshop participants predicted that autonomous vehicles and vehicle-to-vehicle communication will also soon become more common, which could increase roadway capacities and improve safety (15). At the workshop, Google's Michael Cassidy said that improvements in superconducting technology will be crucial for the continued development of electric vehicles, a smart grid, and high-speed trains, and that the increased prevalence of open data systems will help provide more real-time travel information, and further optimize users' travel patterns (15). In addition, real-time data may soon extend to other data sources such as weather, traffic accidents, and environmental emissions, allowing users to react more quickly and save time on their trips (15).

The workshop roundtable also discussed transportation policy and infrastructure investment. One of the points made is that transportation must include more stakeholders and notify them of decisions earlier in the decision making process. Other emphasized that transportation spending should be flatter to support a wider range of modes and that there should be more freight investment. To support these new endeavors, transportation agencies will need to devise and implement new transportation investment mechanisms (15). In developing this new revenue collection framework, governments and municipalities will need to be more nimble to react to changing needs without long periods of legislation. Claire Janisch, CEO of the Genius Lab in South Africa, says that as the economy becomes more global and connected, and as resources become more widely available, people in wealthier countries may need to cut back on some luxuries (15). This reduction could result in less recreational trips and less VMT.

Many of the advancements discussed at the workshop are long-term and society may not achieve them for decades, if at all. However, some of these ideas and innovations, such as medical advancements and transportation financing and governance, can occur incrementally, and thus could affect VMT and fuel tax revenue in Georgia in the next two to three decades.

2.4.3 Commuting in America III: The 3rd National Report on Commuting Patterns and Trends

This extensive report catalogues travel trends in America during the late 20th century and early 21st century. These trends include trip frequency, trip length, trip duration, temporal trip distribution (throughout the day and week), and mode share, among others. These trends were further broken down by region (Midwest, Southeast, etc.) and in some cases by metropolitan area. The report also included specific commuter data, such as how many individuals traveled from the inner city to suburbs (16). Because this report was published in 2006, it does not address more recent economic and fuel price issues; however, it provides perhaps the best concentration of historical travel trends available in one source.

In addition to travel trends, the report provided extensive information on historical population trends at the metro, regional, state, and national levels, migration data, and economic and employment data. Travel data was then associated with demographic data, with travel behavior stratified by ethnicity, age, and location (urban vs. rural) (16).

2.4.4 2017-2025 CAFE Standards Supplemental Report

This document is a joint production of the Environmental Protection Agency (EPA) and National Highway Traffic Safety Administration (NHTSA). It is a response to

President Obama's request to develop a coordinated program under the Clean Air and Energy Policy Conservation Acts to reduce emissions and develop a fleet of next generation clean vehicles for the years 2017-2025.

According to the report, "this National Program would apply to passenger cars, light-duty trucks, and sport-utility vehicles," meaning that it would be a comprehensive nation-wide program (17). Such a program would allow vehicle manufacturers to produce one light-duty fleet for both the EPA and NHTSA to achieve both fuel economy improvements and emissions reductions. The EPA's goal to achieve a standard of 163 g/miles of greenhouse gas (GHG) emissions in 2025 equates to an equivalent 54.5 mpg if fuel economy improvements caused all of the air quality improvements (17). In developing these projections, the EPA and NHTSA worked with vehicle manufacturers to discuss the feasibility of such improvements.

Much of this supplemental report discusses the specifics of the attempted emissions reductions, the timeline and methodologies for achieving these reductions, and the political and organizational cooperation involved. The report notes that full-size pickup trucks will be treated differently than passenger cars and there may be an emissions credit and trading system for the vehicle manufacturers (17).

Appendix Table A.1 from the supplemental report summarizes the quantitative output of projected fuel economy standards. This output is shown in Table 1.

Table 1: Supplemental Report Table A.1 Fuel Economy Predictions (17)

Year	Cars		Trucks	
	Lower	Upper	Lower	Upper
2016	30.96	41.09	24.74	34.42
2017	32.65	43.61	25.09	36.26
2018	33.84	45.21	25.2	37.36
2019	35.07	46.87	25.25	38.16
2020	36.47	48.74	25.25	39.11
2021	38.02	50.83	25.25	41.8
2022	39.79	53.21	26.29	43.79
2023	41.64	55.71	27.53	45.89
2024	43.58	58.32	28.83	48.09
2025	45.61	61.07	30.19	50.39

Although the fuel economy values shown in Table 1 are national level estimates, Georgia does not have its own fuel economy standards; it thus can be assumed that these values are a credible source for projecting future fuel economy.

2.4.5 Deployment Rollout Estimates of Electric Vehicles 2011-2015 (Center for Automotive Research)

This report analyses the different incentives that each state has provided to residents and vehicle manufacturers to entice residents to buy electric or hybrid vehicles. The report is valuable in that is provides these values on a state-by-state basis, based on the current charging infrastructure in place, whereas other reports have only provided national or regional market share projections. It also looks at which companies have invested in hybrid or electric vehicles for their respective fleets. Examples of these companies are General Electric, which announced a purchase of over 25,000 electric vehicles, and Enterprise Holdings, the rental car company, which also announced plans to integrate electric vehicles into its fleet. The location of these companies and their fleets will influence how pervasive hybrid and electric vehicles are in each state. In conjunction with incentives and private fleets, the report also catalogues the deployment of charging infrastructure within each state, based on market demand and government-industry partnerships such as Clean Cities. It then uses these investment projections to predict how many electric vehicles will be purchased in each state in the years 2011-2015 (17). The electric vehicle market share is calculated by comparing the projected electric vehicle sales against total vehicle sales to obtain a vehicle market share percentage. Table 2 shows the projected electric vehicle deployment for Georgia.

Table 2: Projected Electric Vehicle Sales in Georgia 2012-2015 (18)

Year	2012	2013	2014	2015
Projected EV	1,335	2,011	2,358	2,427

2.4.6 Freight Analysis Framework

The Freight Analysis Framework (FAF) is managed by the Federal Highway Administration (FHWA) and integrates a multitude of freight databases to provide a picture of current and projected commodity flows and freight activity in the United States (19). This framework helps this thesis in understanding how freight activity will likely change at the state and federal level. The survey provides freight estimates by weight, value, commodity, and origin/destination for 2007 and projects these estimates through 2040 (19). These flows are assigned to the highway, rail, and water freight networks to model current and predict future congestion. Figure 14 on the following page illustrates the FAF's modeled 2007 commodity flows and its predicted 2040 flows. The figure indicates that Georgia's freight traffic is expected to grow significantly during the next decades (19). This increase in freight growth will both increase fuel tax revenue from freight operations and result in increased maintenance and congestion expenditures.

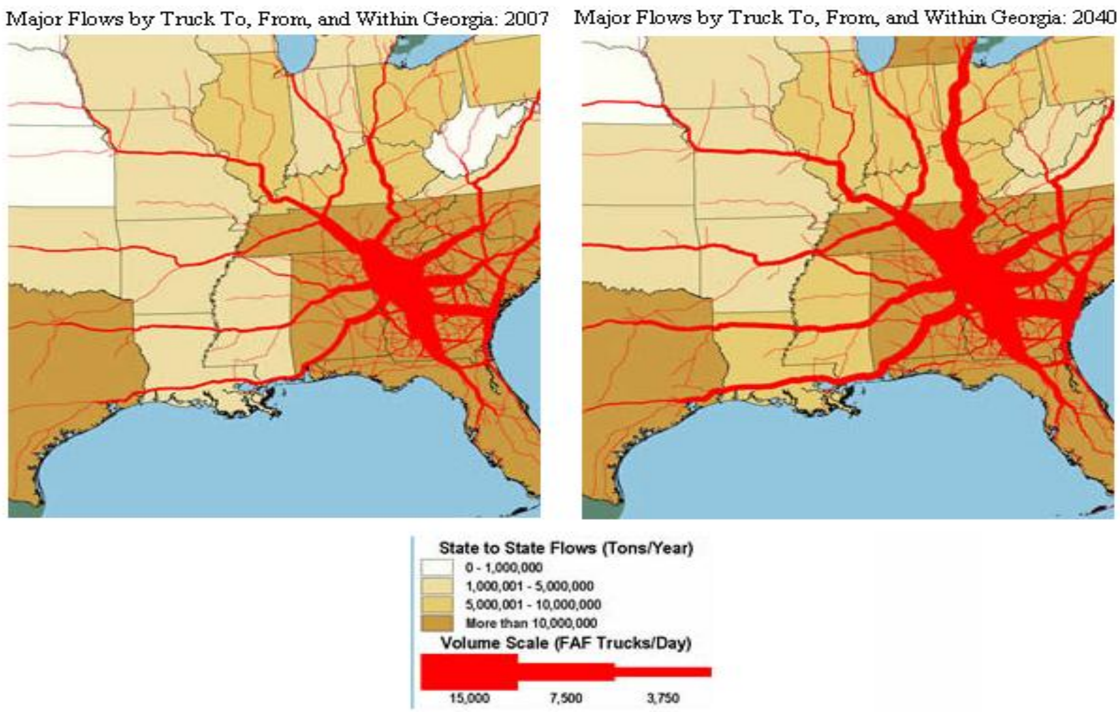


Figure 14: 2007 and Predicted 2040 Truck Freight Through Georgia (19)

2.4.7 Annual Energy Outlook 2011 with Projections to 2035

This report, published by the U.S. Energy Information Administration (EIA), projects the supply and consumption of various energy sources through 2035. In projecting these consumption rates, the outlook identifies legislature at both the state and federal level that has the potential to affect these predictions. In surveying state energy policies, the Outlook found that Georgia was one of 20 states that did not mandate any renewable portfolios (20). This lack of mandates may mean that the Georgia legislature will be less likely to enact laws taxing greenhouse gas emissions or other pollutants in the transportation sector. Such a tax would influence VMT and thus motor fuel tax revenue.

The report also analyzed multiple energy consumption scenarios using a baseline case, a no sunset case that extends current renewable energy incentives and subsidies, and an extended policy case which adopts more stringent fuel economy assumptions. Figure

15 illustrates the projected consumption of transportation fuels through 2035 using these scenarios.

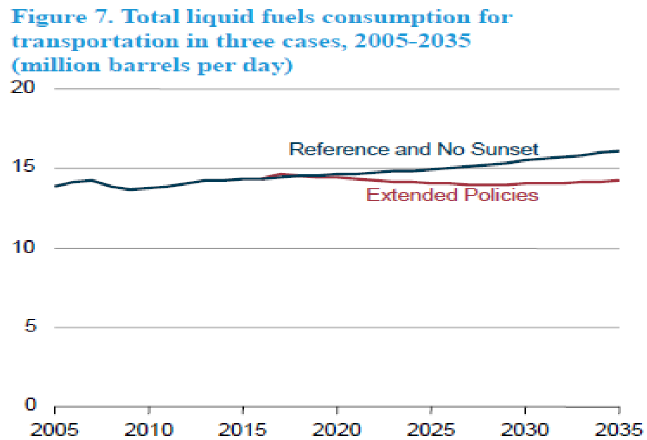


Figure 15: Projected Transportation Fuel Usage Under 3 Scenarios (20)

The report also uses these three scenarios to predict future oil prices. Factors affecting the price of oil include ease of access and extraction, demand for liquid fuels, and the cost of unconventional extraction. Figure 16 illustrates these projected prices.

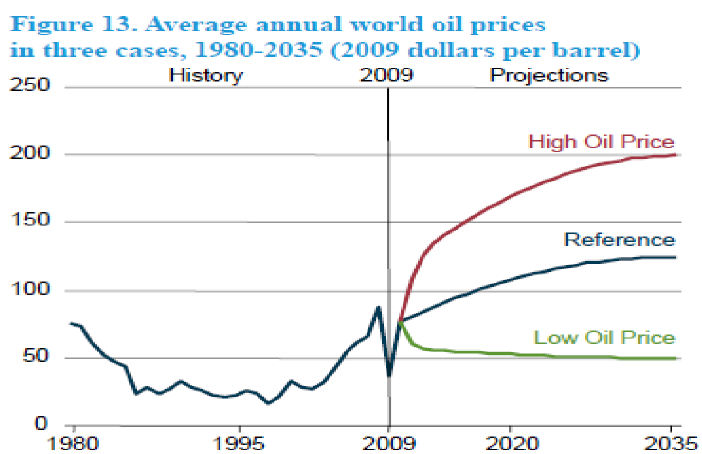


Figure 16: Projected Oil Price under 3 Scenarios (20)

Other projections in the report include vehicle fuel economy based on varying growth rates in the CAFE standards, vehicle market share per vehicle type and price, fuel economy projections for medium-duty and heavy-duty trucks, and annual VMT per licensed driver, as shown in Figure 17. From this figure, one can see that the developers of this report expect annual VMT per licensed driver to continue to increase during the coming decades (20). This prediction contradicts the surveyed MPO regional plans, in which the stated objectives and strategies are designed to reduce VMT in the coming decades.

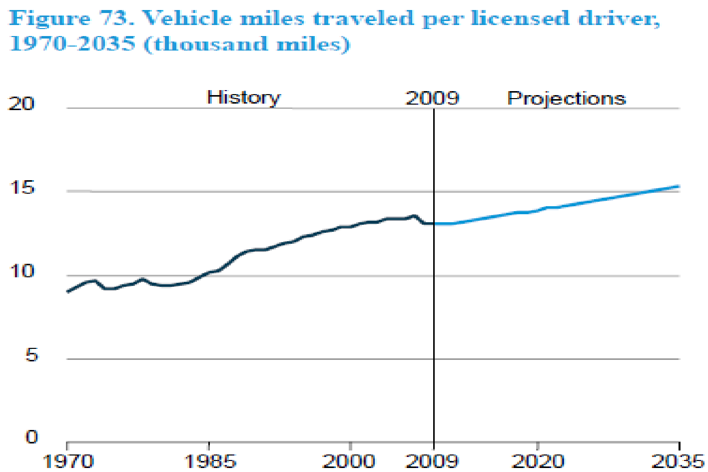


Figure 17: Projected Annual VMT per Licensed Driver (20)

Much of the rest of the report was dedicated to the specific technologies that would influence fuel economy and examining energy trends in non-transportation sectors.

Overall, this report provides a wealth of credible projections across multiple sectors, vehicle types, and energy sources at the national level through 2035. The report was used in this thesis to establish baselines for model predictions and estimates across multiple variables in the energy sector and these estimates will provide upper and lower bounds on the inputs for the fuel tax projection model.

2.4.8 NCHRP 161: System Trials to Demonstrate Mileage-Based Road Use Charges

This report discusses the factors and obstacles one shoulder consider when implementing a VMT-based transportation revenue system. Due to increasing fuel economy, inflation, and the introduction of PHEV's and EV's in recent years, the motor fuel tax has not contributed enough revenue to sustain the Highway Trust Fund. This decline in revenue has prompted some to look to alternative revenue collection mechanisms such as VMT-fees to support transportation infrastructure maintenance and expansion.

NCHRP 161 outlines how to design and conduct large-scale VMT-fee trials to observe potential difficulties and obstacles. These obstacles include organizational and political obstacles, such as citizens' concerns about privacy and how governments would implement and monitor driving, and technical obstacles, such as how new GPS and short-range communication technologies could be employed to tabulate and charge drivers for the distance they drive (21).

The report cites examples and knowledge gained from previously conducted large-scale foreign trials in hopes of applying this knowledge to domestic trials between 2010 and 2015 (21). The implementation and technical lessons learned from these large domestic VMT trials would be collected prior to attempting a national-level implementation by 2020. The report lists goals and performance measures for a VMT-fee system and discusses the different ways in which the program could monitor and charge users and the complexities of each of these strategies (21).

NCHRP 161 provides a solid foundation for understanding the motivation behind VMT-fees, the options for implementing such a system, and the organizational and technical obstacles for implementation. The technical analysis associated with the report is useful in analyzing how agencies would collect revenue, and the analysis of organizational obstacles help in providing a recommendation of whether such a technology would be politically viable.

2.4.9 Tracking National Household Vehicle Usage by Type, Age, and Area in Support of Market Assessments for Plug-In Hybrid Electric Vehicles

This paper utilizes data from the 2009 National Household Travel Survey to stratify vehicle usage (22). Zhou et al. further classify vehicles by age, MSA size, and type. The statistical analysis shows that owners use vehicles 10+ years old much less frequently than newer vehicles and that drivers use newer SUVs three times as frequently as older SUVs (22). The analysis also found that new cars are more popular in urban areas as than in rural areas, and that pickup trucks are more common in rural areas. Owners tend to keep pickup trucks longer than other vehicles but also tend to leave them at home more frequently than other vehicles (22). This finding means that it would take more time to pay off the fuel efficiency benefits of owning a hybrid pickup truck (versus a conventional pickup truck), as it is more frequently left at home.

This statistical report provides insight into vehicle usage on an aggregate and disaggregate basis. It helps vehicle manufacturers understand which owners most utilize their vehicles and the life cycle of different vehicle types in different regions, which could affect vehicle technology development. This is important in Georgia, as the geographic majority of the state is rural; however, the majority of citizens live in the Atlanta metro region and thus qualify as living in an Metropolitan Statistical Area (MSA). This breakdown can be combined with other research to project how new vehicle technologies will be adopted in Georgia and which population segments will adopt them.

2.4.10 New York DOT Interim 2009 Comparison Report, Chapter 4: Urban Travel & Population Density

In this report, authored by Oak Ridge National Laboratories, the New York DOT compares the results of the 2001 NHTS with those of the 2009 NHTS (23). In this specific chapter, they examine the relationships between urban travel patterns and population density (23). Because of its population density, New York City is unique amongst U.S. metro areas and serves as a good region to study the effects how population density influences travel behavior and specifically, VMT. The report uses 2009 NHTS to show that vehicle ownership decreases as population density increases, and that the number of 0-vehicle households increases as population density increases (23). These report finds that these relationship hold both on a national-basis and in New York City. The data also shows that person miles traveled (PMT) decrease as population density increases, with the population density of 4,000 persons/sq. mile a tipping point in this phenomenon (23). This same data also shows that individuals use non-motorized transportation and single-occupancy vehicles less as population density increases (23). The Interim Report includes many other tables and figures that show a strong correlation between increasing population density and decreasing VMT and PMT. The findings from this report can be used to justify including population density as a variable in the projection process.

2.5 Academic Publications

2.5.1 The Motor Use Fuel Tax in Georgia: Collection Efficiency, Trends, and Projections

Clarke, Brown, and Hauer at the Carl Vinson Institute of Government at the University of Georgia wrote this paper in December 2010 to determine if there is a discrepancy between GDOT's actual fuel tax revenue and the revenue it should collect based on fuel economy and VMT. The paper also compares Georgia's fuel tax revenue with other southeast states' fuel tax revenue.

In assessing historical revenue trends, the authors found that due to the sales tax component of the fuel tax, as fuel prices decreased and travel activity increased, fuel tax revenue actually declined, and in 2008 when fuel prices rose abruptly, the opposite occurred and fuel tax revenue increased. Projecting forward through 2020, the authors predict VMT to increase at 1.8% annually and fuel tax revenue to increase 2.4% annually (1).

Although Clarke, Brown, and Hauer's primary objectives differ from that of this research, many of the intermediate goals align, as their research predicts future motor fuel consumption, VMT, and fuel tax revenue. While the research in this thesis creates a unique model, some of the input values and sources referenced in the Clarke, Brown, and Hauer paper proved useful in developing the model described in Chapters 3 and 4. Their paper is especially useful as it is includes the effect of 2008's fuel price increases and recession.

2.5.2 Forecasting Highway Revenues Under Various Options

Agbelie, Bai, Labi, and Sinha at Purdue University published this paper in October of 2010 (24). Their research effort is similar to the research conducted in this report. The research was performed for the Indiana Department of Transportation (INDOT). Another similarity is that the Agbelie et al. paper also predicts revenue under multiple revenue mechanisms, including motor fuel tax and VMT-based fees. While the Agbelie et al. effort utilizes some sources specific to Indiana, it also gleaned information from sources that list values by state, and these sources proved to be valuable for this present thesis as well.

The Purdue model calculates fuel tax revenue by first stratifying vehicles into class by automobile, combination truck, light duty truck, single unit truck, bus and motorcycle, and independently projects VMT for each of these vehicle classifications, using income, GDP, and driving age population as inputs (24). The authors stratify the vehicles in order to obtain more uniform fuel economy classes and to improve fuel consumption studies.

The paper then estimates and projects fuel economy by using an age cohort survival approach, as per INDOTREV-1, the software used for projecting Indiana's fuel tax revenue (24). Within the model, VMT for each vehicle class is distributed by model year and then that particular year's fuel economy is used to calculate fuel consumption for a given vehicle type and model year. The authors used GDP to project freight VMT, and in doing so trucks were split into 29 different weight-based vehicle classifications (24).

The authors projected the number of vehicles in future years using the aforementioned factors of income, GDP, and driving age population as inputs. After the number of vehicles, VMT, and fuel economy is projected, the authors calculated fuel consumption for model year vehicle types by dividing fuel economy into that model year vehicle type's VMT. This fuel consumption was then used to predict motor fuel tax revenue based on different revenue collection frameworks including the motor fuel tax (baseline), VMT-based fees, and by adjusting fuel taxes to inflation. The authors used price elasticities when projecting toll or fee-based revenues to properly assess the impact of changing transportation costs on travel behavior (24).

The Agbelie et al. paper provides a wealth of practical knowledge in understanding how to create a revenue prediction model, despite the fact that its intended use is for another state. It is especially useful for this thesis as it also projects revenue using alternative revenue methodologies.

2.5.3 The Future Isn't What It Used To Be: Changing Trends and Their Implications for Transport Planning

Todd Litman of the Victoria Transport Policy Institute wrote this report to "examine demographic, economic, and market trends that affect travel demand." Unlike the previous two academic reports (2.5.1 and 2.5.2), which attempted to model future fuel tax revenue, this report examines factors that affect travel behavior (25).

Many of the trends listed within Litman's report conflict in how they would affect VMT. The trends he identifies that would likely increase per capita VMT are decreasing household size, longer life-span, modified eating habits, increasing trip frequency, increased children's activities, and more frequent long recreational trips (25). Decreasing household size implies a greater number of households, which in turn means more independent trips and thus more VMT. A longer life span likely also means increased VMT due to increased population size and the fact that elderly would likely be able to drive at a later age. Litman also posits that households are eating out more often, which may mean greater VMT, although these trips are often chained with other trips (25). However, these other trips, such as children's activities, are also increasing in frequency, which increases VMT.

Some of the trends that he identified that would likely decrease VMT are online purchasing, a saturation in automobile ownership, decreasing automobile ownership among those 16-19 years of age, and increased trip chaining (25). Online purchasing allows individuals to shop without accruing VMT on shopping trips. Saturated automobile ownership implies that VMT growth would likely approach an asymptotic value. A decrease in automobile ownership among teenagers might work to offset any gains in VMT that would be seen from the baby boomer generation or increases in life expectancy. Trip chaining optimizes one's route and reduces the VMT accrued when starting each trip from home. Figure 18 on the following page illustrates the decreasing percentage of teenagers with a driver's license. It is important to note that this decrease occurred prior to the 2008 economic recession and thus this decrease in driver's license permits is likely independent of the recession.

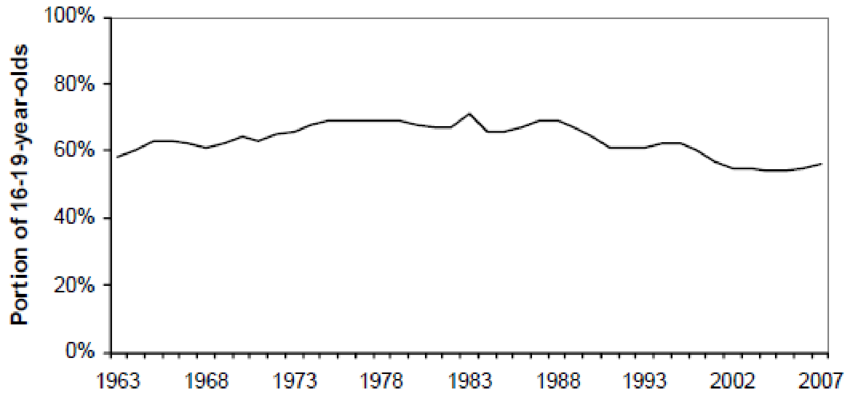


Figure 18: Percentage of 16-19 Year Olds with a Driver's License from 1963 to 2007 (25)

Litman also includes a table that predicts how different factors will influence travel demand. This list of factors is shown in Table 3.

Table 3: Factors Affecting Future Travel (25)

Factor	Impacts on Vehicle Travel Demands
Demographics	Significant declines likely due to aging population, retiring baby boom.
Income	Mixed. Increased mileage likely among groups that shift from low- to medium-income, but little growth likely among middle- and higher-income groups.
Operating costs	Moderate to large declines likely over the long term due to rising fuel prices, and possibly more road tolls.
Travel speeds	No change expected.
Land use patterns	No change or decline likely due to increased urbanization and more smart growth development.
Planning and investment practices	Some declines likely, particularly in urban areas, due to increased highway congestion, improvements to alternative modes and more mobility management.
New technologies	Some declines likely due to improved alternative modes (particularly more telework and public transit user information), and traffic management (better road and parking pricing systems allow more deployment of user fees).
Consumer preferences	Some declines likely due to increased preference for alternative modes, urban living and walkable communities (motivated in part by health concerns).
Environmental concerns	Some declines likely due to energy conservation and emission reduction programs that include VMT reduction targets, leading to more mobility management.
Freight transport	Further growth, but the growth rate will probably decline and be concentrated on certain corridors.

This table summarized various factors expected to affect future vehicle travel.

Many of the factors and trends discussed in Litman's report are similar to those outlined in the MPO and state transportation plans described in sections 2.1 and 2.2. This research will consider each factor both independently and interactively for their affects on VMT.

2.5.4 If Cars Were More Efficient Would We Use Less Fuel?

Kenneth Small and Kurt Van Dender wrote this article in the fall of 2007 for the University of California's transportation research periodical. The article analyzes recent fuel price elasticities in California to evaluate the rebound effect at different fuel prices. The rebound effect describes how fuel economy improvements can counteract fuel price increases. Understanding this concept is important when relating fuel price, fuel economy, and VMT.

The Small and Van Dender article describes two parts to the driver response to increasing fuel prices. First, VMT decreases by a given percentage due to increasing fuel prices (26). If these prices remain high, consumers usually respond by purchasing more fuel-efficient vehicles. These fuel efficiency improvements allow drivers to travel the same distance by purchasing less fuel. If drivers use this increase in fuel efficiency to drive more than they did prior to the efficiency increase, there is a rebound effect. The magnitude of this rebound influences how effective CAFE standards mandating increased fuel economy can be at reducing emissions, total VMT, and motor fuel tax revenue

Small and Van Dender explain that the magnitude of the rebound effect declines with rising income, as time becomes more important than fuel costs, and that the magnitude increases as fuel costs rise and they become a more significant factor in a household's budget (26). The authors believe that the rebound effect will continue to decline with increasing urbanization, as the time costs associated with congestion dominates fuel costs (26). The article concludes by stating that elasticities have continued to decline into the 21st century and that the rebound effect in the first decade of the 21st century was less than 6% (26). However, this particular elasticity may no longer be relevant, as the article was published in 2007 and thus does not account for the fuel price and fuel economy increase seen since 2008.

2.5.5 3rd Symposium on Mileage-Based User Fees

This paper was included as a part of the 2012 TRB conference and it collates VMT-fee knowledge and lessons learned during 2011. Specifically, it asks how agencies can best implement VMT programs, how agencies should coordinate VMT research and policies, and how governments and agencies can best increase public acceptance of a new transportation funding mechanism. At the symposium, attendees stated that they believed that state implementation (as opposed to federal) would be the most effective means of administering a VMT-fee program. Attendees also stressed interoperability, meaning that the program should only charge drivers once per period and that one account should handle all VMT-related charges (27).

Two of the biggest concerns discussed during the symposium were public acceptance and administration costs. An I-95 corridor study stated that administration and operation fees could cost as much as 6%-20% of revenue, while New Zealand has had a VMT-fee program in place since 1977 and its administration costs only 3% of revenue (27). The article also states that administering the motor fuel tax program costs only 0.82% of revenue (27). Government distrust and privacy issues contributed most to citizens' concerns. A survey found that the elderly were most concerned about privacy issues, and that increased schooling and VMT-fee education and marketing increased approval for the program. Also important for implementation, trucking companies were concerned about the new system, as the motor fuel tax is applied upstream to fewer than 1,000 companies, and a VMT-fee would be applied to individual customers. Truckers were concerned about this bureaucracy and the costs it would impose on their business (27).

The findings from the symposium help in assessing which issues are the most critical in implementing a VMT-fee revenue system. Of particular interest is the fact that citizens were more receptive to such a system with increased marketing and information. Truckers' business concerns are also an important issue.

2.5.6 What Do Americans Think About Federal Transportation Tax Options? Results From Year 2 of a National Survey

Agrawal and Nixon present the results of a random-dial telephone survey conducted in March and April of 2011 to understand citizens' response to different transportation tax options. Support varied by taxation type, tax rate, and finance intent. In addition to the survey conducted in the paper, the paper also summarizes the results of other recent transportation tax public opinion polls. Figure 20 on the following page summarizes the response rates for each taxation type. From the figure, it is apparent that citizens gave the highest support to a 10¢/gallon motor fuel tax increase directed to road maintenance projects with a 10¢/gallon increase directed to safety a close second. Only 22% of respondents supported a 1¢/mile VMT-fee, the lowest respond rate of any of the options presented (28).

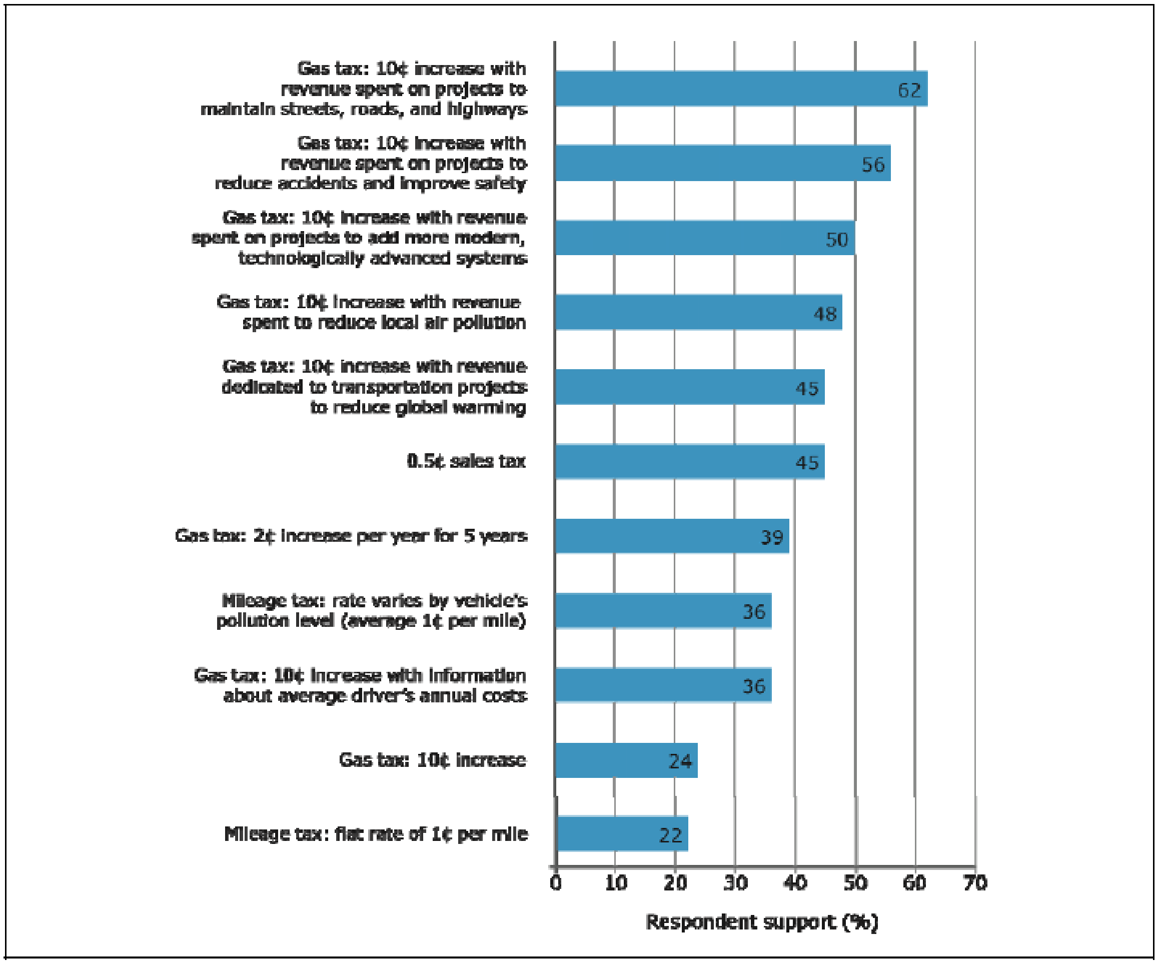


Figure 19: Survey Response Rate to Various Taxation Measures (Agrawal & Nixon) (28)

This paper illustrates that tailoring the description and funding targets for motor fuel tax increases or alternative revenue strategies can increase the public's support for these funding mechanisms. Understanding how to gain public support for these taxation measures is an important component of providing a recommendation for alternative revenue mechanisms.

2.6 Futurist Predictions

2.6.1 Transport Revolutions: Richard Gilbert & Anthony Perl

This book provides an in-depth look at how the transport of people and goods occurs in today's society, the energy required to facilitate this transport, the emissions that result from this activity, and how the increase in fuel prices in 2008 changed transportation activities (3). Per its title, the book also examines several previous "transport revolutions," such as the advent of Britain's railways from 1830-1850, the modal change in transatlantic travel in the 1950s, and the advent of high-speed rail in Europe and Japan from 1960-1985. The authors predict that increasing fuel prices, congestion, and resource scarcity will lead to another transport revolution in the coming decades. From this postulation, they project travel behavior and energy usage under various scenarios in 2025 (3).

In conjunction with these projections, Gilbert and Perl also provide recommendations for how to reduce global energy consumption through 2025. Although many of their predictions are aggressive for a now 13-year timeframe, they may be less aggressive for more distant time frames. Some of their predictions include the use of electric jitneys and on-demand personal rapid transport (PRT) vehicles, and widespread electrification of mass transit. They also predict significant increases in intercity bus and rail service and significant declines in domestic aviation by 2025. Other predictions include changes in freight transport, such as the use of truck trolleys and trucks with batteries, increased rail activity, dramatic decreases in pipeline activity, and declines in ocean freight, as regions revert to more local economies (3). If economies do revert to being more locally focused, then freight VMT in Georgia might decline significantly, as container traffic at the Port of Savannah would decrease sharply and there would be fewer freight trucks on Georgia's roads.

Transport Revolutions provides a strong foundation for understanding how energy and transportation interact and also presents a wealth of information on current energy production and consumption.

2.6.2 $20 Per Gallon: How the Inevitable Rise in the Price of Gasoline Will Change Our Lives for the Better: Christopher Steiner

In this book, Steiner predicts what would occur as the price of gasoline increases from $4 to $20. Each chapter projects what would occur with a $2 increase in gas price. Although it is unlikely that fuel prices will reach $20 during the scope of this research, $6 gasoline in the next two decades is entirely possible. At $6 per gallon, Steiner predicts that sport utility vehicles will all but disappear, and that only those who absolutely need light-duty trucks will own them. He predicts more urban living due to increased commute costs and discusses the ancillary health benefits of living in a more walkable community. Advancements in vehicle technology and more innovative transportation revenue methods such as congestion pricing are also analyzed (29).

This book was helpful in understanding the potential changes that could accompany various tiers of fuel price increases and was helpful in understanding that people's psychological response can vary significantly across a small price threshold (29). While fuel prices will likely not increase $16 dollars in the next two decades, some of the impacts and changes mentioned in the $6, $8, and $10 chapters may be seen and felt prior to fuel prices actually reaching these respective levels.

2.6.3 The Next Hundred Million: America in 2050: Joel Kotkin

This book is a futurist projection of America in 2050 with 100 million additional residents. Kotkin predicts how cities will change and adapt to increases in population, fuel price, and energy scarcities. He predicts vast changes in suburban America, as baby boomers age and require more proximate restaurants and activities. He also predicts that families will become more nuclear, with more generations living together and that commutes will decrease as more individuals work at home (30). Kotkin's projections include the possibility of Atlanta becoming a "city of aspiration," that will provide the same upward mobility that industrial cities like New York and Chicago once provided (30). Kotkin also projects that polycentric cities will become the norm and that a region's main downtown will become less and less vital (30).

Kotkin's other projections include the idea that telecommuting will transform rural areas into economic hotspots by allowing call-centers and online trouble-shooting services to capitalize on cheap labor in rural areas such as the Great Plains and places like rural Georgia (30). Such employment patterns would likely reduce VMT in these areas.

Kotkin's book provides few quantifiable predictions for use in this research or a model, but it does provide a background on the history of urban and suburban living and helps one to understand what factors may influence individuals' future housing choices.

2.7 Databases

2.7.1 2009 National Household Travel Survey

The 2009 National Household Travel Survey (NHTS) is a comprehensive travel survey administered by the FHWA in 2008-2009. The survey sampled over 150,000 households in twenty states, one of which was Georgia (31). The survey collected travel information such as trip frequency, trip distance, annual VMT, origin and destination information, mode type, and relevant automobile information, such as fuel economy and model year. The survey also collected demographic information such as household size, vehicle ownership, and household income (31). The data from the NHTS is publically available and this thesis incorporates NHTS data in its motor fuel tax revenue model.

In addition to the data from the 2009 NHTS, several related reports assisted the author in understanding the data collection efforts and the resulting data. The User's Guide explains the survey's data collection methodologies and sample size goals as well as decoding the variable abbreviations used within the database (32). The Summary of Travel Trends tabulates and graphically summarizes the result of the 2009 NHTS on a national and regional level. This report also used the data gleaned from the 2009 survey to create time-series comparisons with similar variables from past national household travel surveys in order to observe recent travel trends (33).

2.7.2 US Census Bureau

The revenue projection model developed for this thesis needed statewide demographic data to validate and extrapolate the 2009 NHTS data discussed in section 2.7.1. The U.S. Census Bureau's 2009 American Community Survey (ACS) data was used for this purpose. The ACS does not sample every household, but rather uses a smaller sample to update and project data from the larger-scale, decennial census. The 2009 release of the ACS averages data from 2007-2009 to calculate income distribution and vehicle ownership data at the statewide level in Georgia (34). This thesis then incorporates this data in its motor fuel tax projection model. Chapter 3 further explains how the model incorporates and uses this data.

2.7.3 Federal Highway Performance Monitoring System

The FHWA's Highway Performance Monitoring System (HPMS) is a national program that gathers data about the use and condition of the nation's highway system. The HPMS gathers data from each functional road class in many counties to ensure that the program has established a sufficient sample size prior to extrapolating data to the state and national level (35). This research used the HPMS data to project heavy truck VMT and as a credible source by which to validate the model's 2009 VMT projections.

CHAPTER 3

MODEL DEVELOPMENT

3.1 Factor Identification and Database Selection

The sources mentioned in Chapter 2 provide a foundation for understanding qualitatively how demographic, energy and environmental, political, and technological factors affect VMT and fuel economy in Georgia. These factors influence fuel consumption via government mandates, consumer market response, and technological advancement. To create a model to project future revenue, quantitative sources were needed. Some of these sources contained regional and data while other sources provided national-level values, depending on the variable. Section 2.7 provides a synopsis of the databases utilized. Some of the literature surveyed made Georgia-specific projections, while most only gave national projections. Once a thorough literature review had been conducted that identified the factors that influence VMT and fuel economy, a model was created to transition the research from a qualitative to a quantitative framework that output fuel tax revenue.

A recent and Georgia-specific travel database was critical to this quantitative framework. The 2009 National Household Travel Survey provides the most recent source of detailed household including income, persons per household, and vehicles per household; travel behavior data including trips per day, miles traveled; and vehicle data, including vehicle age and fuel economy (average miles per gallon). Figure 21 outlines the literature review, factor identification, and database selection process.

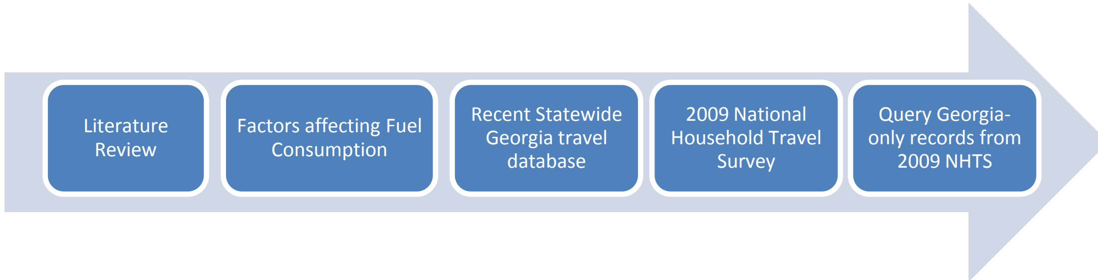


Figure 20: Data Search Process

Figure 21 shows that the model need to parse Georgia records from the 2009 NHTS in order to generate statistics specific to Georgia. The author made queries using Microsoft Access to create multiple databases in order to relate different variables to VMT and to better understand these relationships.

3.2 2009 Model Fleet Segmentation

Prior to projecting future motor fuel tax, the model was first used to estimate 2009 VMT and fuel tax revenue to compare with known 2009 values. This served to validate the model's logic before projecting future VMT and fuel tax revenue. The model was constrained to a 2009 validation because of the decision to use the 2009 NHTS as the travel database. This limited all of the other variables in the model to their respective 2009 values. Figure 22 on the following page, shows how fleet VMT and fleet fuel economy contribute directly to fleet fuel consumption.

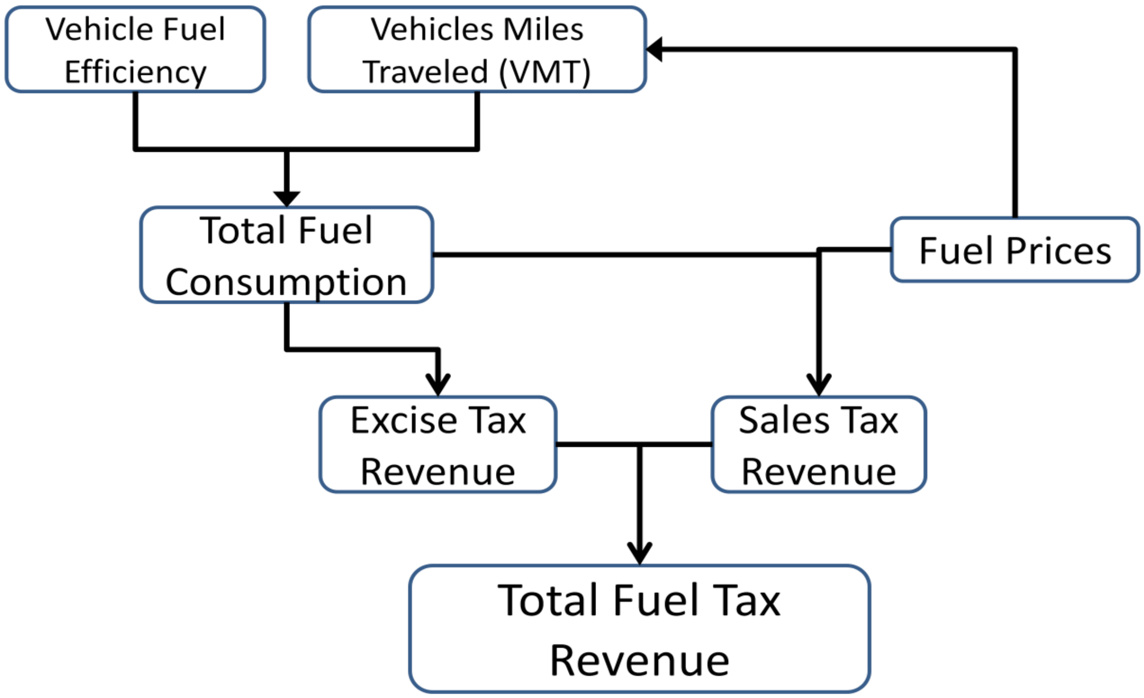


Figure 21: Factors Contributing to Fuel Tax Revenue

Figure 22 also illustrates how fuel consumption and the fuel price influence the sales and excise taxes, which sum to total fuel tax revenue. To obtain more precise results, the model stratifies the fleet by vehicle type. This same methodology was also used by multiple other research efforts including those by Vasudevan and Nambisan, Agbelie et al., and Pickrell et al. (36) (37) (24). This segmentation increases precision because one can assign more exact fuel economies to each vehicle type than to the fleet as a whole. Another benefit to stratifying the fleet is that it provides transportation agencies the revenue share for personal vehicles, freight trucks, and transit vehicles, which better informs officials of each fleet's and revenue contribution.

The model splits the fleet into personal, freight and transit segments, with the personal and freight categories further split. The remainder of this chapter details the VMT and fuel economy calculation methodologies for each fleet segment and compares the modeled values with NHTS reported values.

3.3 Personal Fleet Calculation Methodology

For the purposes of this research, personal vehicles represent any automobile (car, pickup truck, SUV) that one owns and drives for personal use. Modeling 2009 fuel vehicle tax revenue from these vehicles required knowledge of Georgia's household travel behavior to calculate VMT and Georgia's 2009 personal fleet fuel economy.

3.3.1 2009 Personal Vehicle VMT Calculation

The literature presented in Chapter 2 illustrates the wide range of variables that influence travel behavior. These include demographic, economic, technological, political, and environmental factors, some of which are difficult to represent quantitatively. The 2009 NHTS captures many demographic variables, such as persons per household, vehicles per household, household income, age, gender and, housing location. Although many variables influence VMT, the model's structure requires a "main explanatory variable." The author chose this variable by surveying the literature and by comparing variables against VMT from 2009 NHTS' Georgia records. Figure 23 illustrates the "main explanatory variable" selection process.

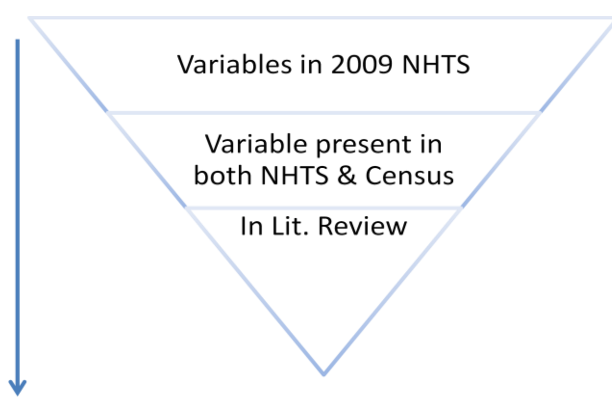


Figure 22: Thought Process for Selecting Main Household Decision-Making Variable with Respect to VMT

Figure 23 shows that the model requires that both the NHTS and ACS contain the main variable. This requirement is necessary so that the model can scale the average VMT per household values obtained from the 2009 NHTS sample to state total using the ACS (31). In choosing a main variable, the author stratified VMT data for each potential explanatory variable. For example, if vehicles per household was chosen as the main explanatory variable, then Microsoft Access and Excel were used to calculate average VMT for households with 1 vehicle, 2 vehicles, 3 vehicles, etc. using the 2009 NHTS database. This average VMT per vehicle ownership value was then multiplied by the total number of households matching the given bin's criterion in Georgia (i.e. by the total number of households in Georgia with 1 vehicle, 2 vehicles, 3 vehicles, etc.). The number of households in the state satisfying this data was obtained from the 2009 ACS data. Table 4 illustrates this categorical-proportional calculation process..

Table 4: Generic VMT Extrapolation Example

Generic Statewide VMT Extrapolation Example					
	VMT per Group for Given Variable (NHTS Data)				
	Households/ VMT	Group 1 Avg VMT	Group 2 Avg VMT	Group 3 Avg VMT	Group n Avg VMT
Households per Group (ACS)	GA Households in Group 1	Group 1 State VMT			
	GA Households in Group 2		Group 2 State VMT		
	GA Households in Group 3			Group 3 State VMT	
	GA Households in Group n				Group n State VMT
Sum of highlighted cells is the total personal VMT driven by Georgia households					

Table 4 indicates a generic example of the process that calculates total statewide VMT. The author performed this process with multiple variables from the 2009 NHTS and evaluated the results prior to selecting a final main explanatory variable. After calculating VMT with multiple variables, the author selected household income as the main explanatory variable for multiple reasons. First, income was classified into 8 groups in the 2009 NHTS, which was significantly more groups than other variables such as vehicles per household (3 bins) or persons per household (5 bins) (31). This finer stratification resulted in more precise VMT calculations. A recent paper by Blumenberg and Pierce presented at the 2012 Annual TRB Conference also supports income's strength as an explanatory variable for VMT in the 2009 NHTS (38). Blumenberg and Pierce found that "automobile ownership increases with household income, even after controlling for other determinants of automobile ownership." They concluded that not only do "low-income adults travel less […] than higher income adults," but "low-income and higher-income households [convert] income to automobiles much faster than the middle class" (38). McMullen and Zhang and a state-level VMT forecasting effort directed by the U.S. DOT's Volpe Center also used income in projecting VMT from personal travel (39) (37). This research provides strong support to use income as the explanatory variable for both the 2009 model and in the projection models. In addition to its strength predicting VMT, income can also correlate with other variables such as vehicle age, fuel economy and even economic forecasts. These relationships prove useful in the projection process discussed in Chapter 4.

The model uses the matrix method outlined in Table 4 to project VMT from income. Table 5 shows how many households were in each income cohort for both the statewide ACS Survey and the 2009 NHTS sample size, and Figure 24 compares average household VMT by income cohort using the 2009 NHTS data.

Table 5: Households per Income Cohort in Georgia in 2009 (U.S. Census Bureau: American Community Survey)

Income Level	Census Households	2009 NHTS Sample Size
Less than $10,000	309,460	424
$10,000 to $14,999	218,442	382
$15,000 to $24,999	404,891	771
$25,000 to $34,999	382,966	781
$35,000 to $49,999	505,170	1082
$50,000 to $74,999	631,944	1163
$75,000 to $99,999	403,497	868
$100,000+	612,880	1051

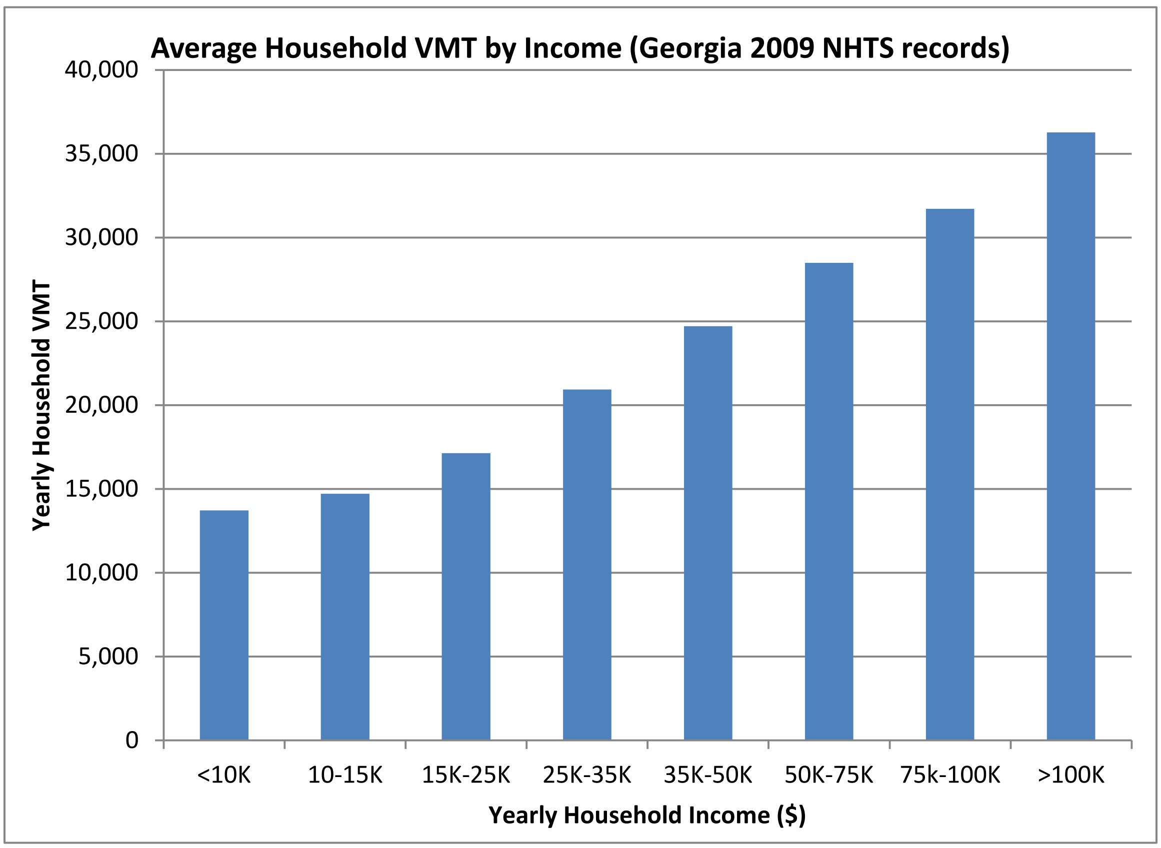


Figure 23: Average VMT by Income Cohort in Georgia in 2009 (31)

One can see from Figure 24 that there is a relatively linear increase in VMT as average household income increases. This consistent increase, combined with

Blumenberg and Pierce's findings support the view that income can be used to project VMT from the 2009 NHTS. Table 6 uses the methodology outlined in Table 4, the household data from Table 5, and the VMT versus income relationship from Figure 24 to calculate the total VMT for Georgia households in 2009.

Table 6: 2009 Personal VMT Calculations by Income Cohort for Georgia Households (31) (34)

2009 Personal VMT Calculation by Income cohort (in billions)									
Income Classification		VMT per Income Classification							
		0-10K	10-15K	15K-25K	25K-35K	35K-50K	50K-75K	75k-100K	>100K
Total households	**3,469,250**	13,716	14,722	17,133	20,941	24,705	28,488	31,710	36,265
Less than $10,000	309,46	4.24							
$10,000 to $14,999	218,442		3.22						
$15,000 to $24,999	404,891			6.94					
$25,000 to $34,999	382,966				8.02				
$35,000 to $49,999	505,170					12.48			
$50,000 to $74,999	631,944						18.00		
$75,000 to $99,999	403,497							12.79	
$100,000+	612,880								22.23
Total Personal VMT (billions):									87.92

Table 6 shows that this calculation methodology results in an estimated total 2009 Georgia personal VMT of 87.92 billion vehicle miles. A limitation of this estimation method is that it only accounts for VMT driven by Georgian households and does not account for miles driven in Georgia by other states' households. Thus, the miles driven by other states' households in Georgia do not register using this method. Conversely, the method also counts miles driven by Georgian households in other states as well as those driven in Georgia. Intuitively, due to Georgia's tourism and location just north of Florida, another major tourist destination, more miles would likely be driven in Georgia by vehicles registered outside of Georgia than vice versa. Thus, the author believes that this method slightly underestimates VMT.

3.3.1.1 VMT Segmentation By Vehicle Model Year

In order to calculate personal vehicle fuel consumption, an intermediate step in calculating motor fuel tax revenue, the model needs precise fleet fuel economy estimates. Instead of calculating an overall average fleet fuel economy or even fuel economy by vehicle type (car, truck, SUV, etc.), this model segments personal vehicles by model year. Abgelie et al. used this same model year segmentation method in 2010 at Purdue University as discussed in section 2.5.2 (24). In this thesis, the author uses NHTS vehicle age data to segment the vehicles in the sample by model year. Figure 25 shows the distribution of VMT by vehicle age as a percentage of total 2009 NHTS VMT and the sample size percentage by model year. Table 7 illustrates the total number of vehicles that were sampled per vehicle model year.

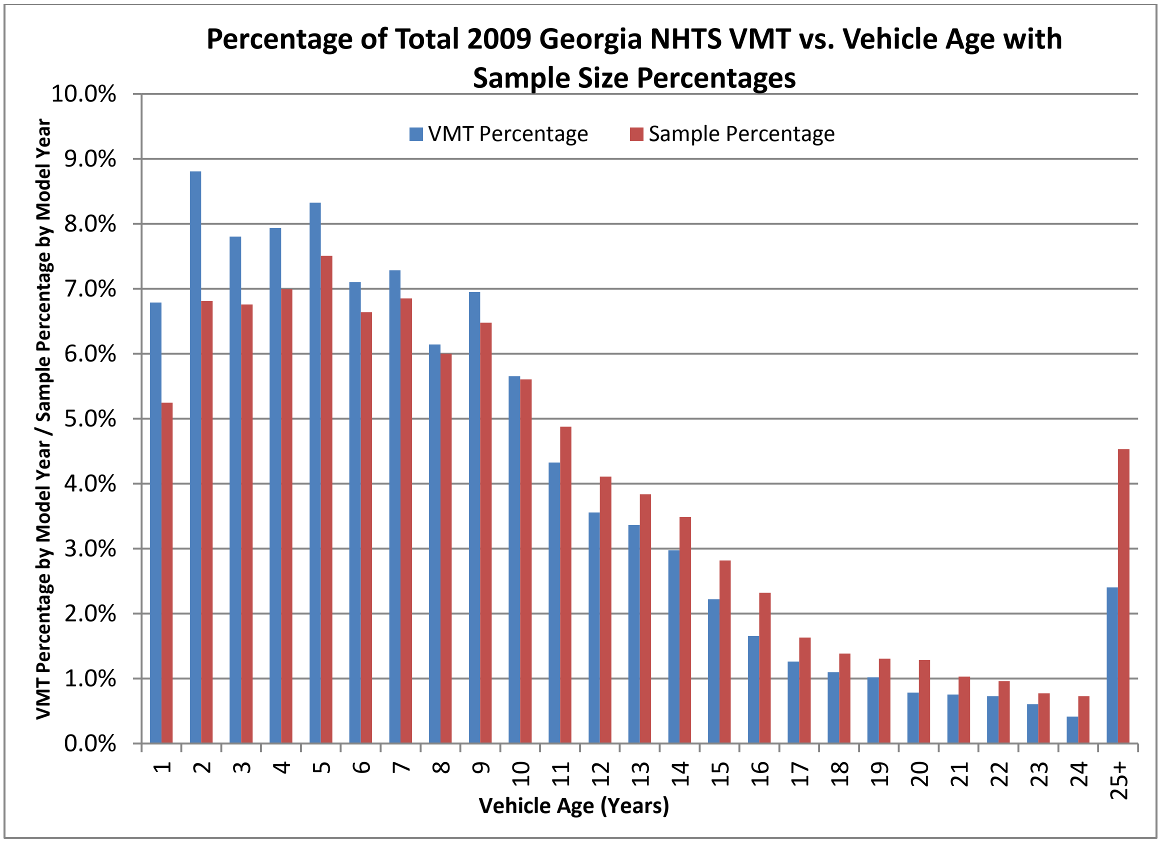


Figure 24: Percentage Distribution of Personal VMT by Vehicle Age

Table 7: VMT Model Year Distribution Sample Size

Vehicle Age	1	2	3	4	5	6	7	8	9	10	11	12
NHTS Sample Size	800	1039	1031	1067	1145	1013	1045	915	988	855	744	627
Vehicle Age	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25+**
NHTS Sample Size	532	430	354	249	211	199	196	157	147	118	111	691

Figure 25 indicates that newer vehicles traveled the majority of VMT in the NHTS sample and that annual VMT declines with increasing vehicle age. The right most bar representing VMT of vehicles 25 years and older is significantly higher than the other bars near it because it includes VMT for multiple model years. After calculating the percentages for each model year, the percentages were then multiplied by the total personal VMT value of 87.92 billion miles calculated in Table 6 to obtain VMT per model year. Figure 25 and Table 7 also indicate that the NHTS sampling percentages were in close accordance with the VMT usage percentages.

3.3.2 Personal Vehicle Fuel Economy Calculation Methodology

As was discussed in Section 3.1, one must know both VMT and fuel economy to calculate fuel consumption, the precursor to calculating fuel tax revenue. As with VMT, personal vehicle fleet fuel economy was also stratified by model year, which resulted in more precise fuel economy and consumption outputs. Again, Agbelie et al. at Purdue University employed this same methodology in projecting short-term motor fuel tax revenue for Indiana in 2010 (24). This model uses the 2009 NHTS dataset to calculate the average fuel economy of each model year. Figure 26 illustrates these fuel economies.

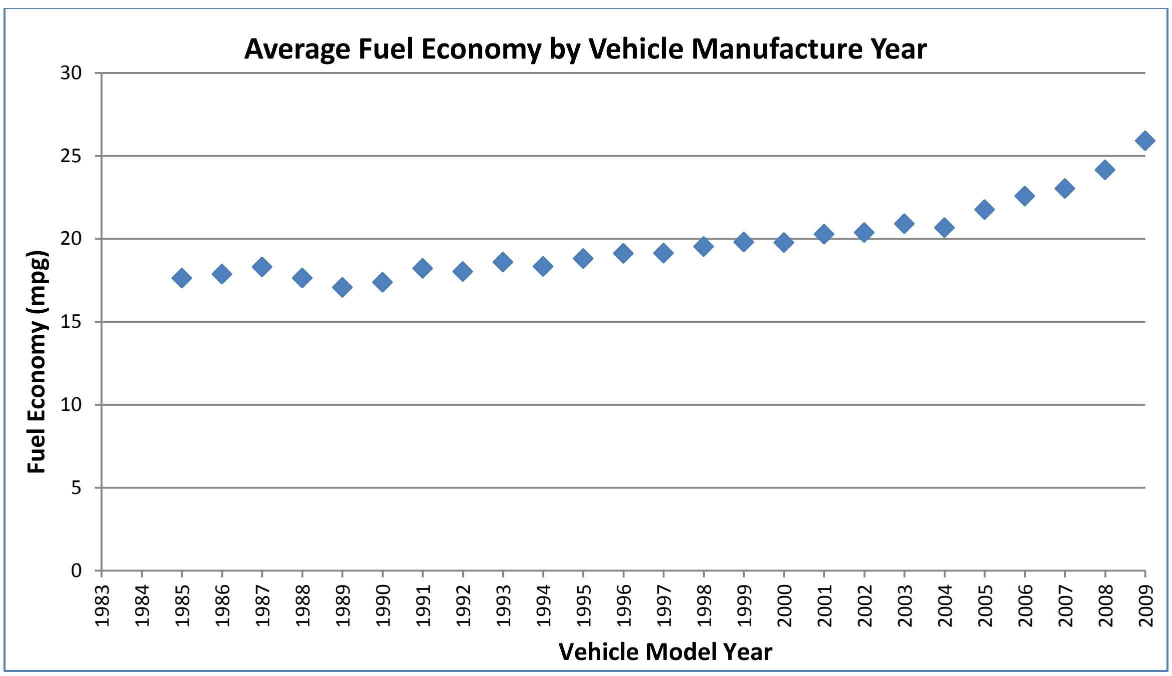


Figure 25: Average Fuel Economy Distribution by Vehicle Model Year (31)

One can see from Figure 26 that the average fuel economy of each model year has increased from an average of approximately 17 mpg in 1984 to approximately 26 mpg in

2009. Again, this dataset includes personal vehicles of all types such as cars, light-duty trucks and SUVs.

3.3.3 Fuel Consumption Calculation

Sections 3.3.1 and 3.3.2 explained how the model calculates average personal vehicle VMT and fuel economy by model year. The model uses these two inputs to calculate fuel consumption per model year. The model then sums each model year's fuel consumption to calculate total personal vehicle fuel consumption. Figure 27 illustrates the overall fuel consumption methodology.

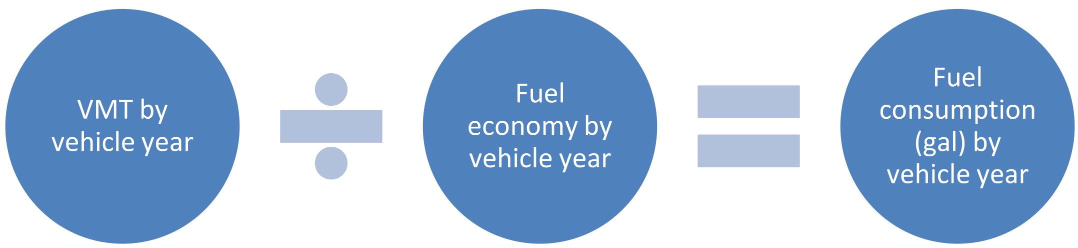


Figure 26: Fuel Consumption Calculation Methodology (by Vehicle Model Year)

Table 8 provides an abbreviated example of the process used to calculate fuel consumption by vehicle model year and the results it produced. Table 8 shows only four of the twenty-five model year categories; the full calculation process can be seen within the model itself.

Table 8: Example of Fuel Consumption Calculation Output

Vehicle Age (years)	1	2	3	4…
Percent of Total VMT by Vehicle Age	6.79%	8.81%	7.81%	7.94%..
VMT by Vehicle Age (billion)	6.05	7.85	6.96	7.08…
Average Year Fuel Efficiency (mpg)	25.9	24.2	23.0	22.6…
Fuel Consumption by Year (million gallons)	234	325	302	314 …

3.3.4 Personal Vehicle Revenue Calculation

Once the model had output fuel consumption for each vehicle model year, the only step that remained in calculating revenue from personal vehicles was to apply the appropriate excise rate and sales tax percentage for the two components of Georgia's motor fuel tax. Table 9 shows Georgia's current tax rates and the corresponding revenue for both taxes. The table displays only four of the twenty five model years due to space limitations.

Table 9: Sample Fuel Tax Receipts of Personal VMT after Applying Tax Rates & Percentages

Vehicle Age (year)	1	2	3	4…
Percent of Total VMT by Veh Age	6.79%	8.81%	7.81%	7.94%...
VMT by Vehicle Age (billion)	6.05	7.85	6.96	7.08…
Average Year Fuel Efficiency (mpg)	25.9	24.15	23.03	22.57…
Fuel Consumption by Year (million gal)	234	325	302	314…
Excise Tax Receipts ($)	$ 17,291,754.85	$ 24,050,480.43	$ 22,349,912.31	$ 23,195,085.19
Sales Tax Receipts ($)	$16,316,499.88	$22,694,033.34	$ 21,089,377.26	$ 21,886,882.38
	Gas Price	Tax Per Gallon	Sales Tax Percent	
	$2.10	$0.075	3%	

Table 9 shows the revenue collected for each vehicle model year based on the amount of gallons consumed, the prevailing fuel price, and tax rates. The fuel price of $2.10 was obtained using historical data from www.GasBuddy.com, which uses user-reported data from gas stations throughout the nation and by using the tax rates to work backwards to the pre-tax price (40). McMullen and Zhang also employ this method of obtaining pre-tax fuel prices when they evaluate equivalent VMT fees to compare with motor fuel tax rates (39). To obtain the gas price in Georgia, www.GasBuddy.com's "historical charts" feature was used to query the gas price in the state during GDOT's

2009 fiscal year, which spanned July 2008 to June 2009 (40). The model averaged the price over this period under the assumption that drivers consumed fuel evenly throughout the timeframe. The price obtained from this averaging process was $2.45; however, in order to accurately calculate the tax revenue, one first needed to deduct the two components of the state fuel tax and the federal fuel tax from the reported fuel price. After dividing $2.45 by the 4% sales tax applied to gasoline in Georgia and then subtracting the 7.5¢ and 18.4¢ state and federal excise taxes, the resultant pre-tax initial fuel price was $2.10, which is shown in Table 9. The model must divide by 4% instead of 3% because there is an additional 1% sales tax on fuel that goes to the state's general fund. Although this paper uses the state and federal fuel taxes to work backwards from the price at the pump to obtain the pre-tax price, companies pay taxes at the wholesale level, much further upstream in the distribution process (1).

While the methodology for calculating both the VMT and fuel economy for personal vehicle is sound, some limitations do exist. These include the aforementioned discrepancy of not accounting for out of state vehicle VMT within Georgia, and possible sampling error within the 2009 NHTS's survey procedures. Such error could affect values such as the distribution of VMT by vehicle model year and model year fuel economies.

3.4 Freight Fleet Revenue Calculation & Methodology

The nation's economy depends on long and short haul freight transport to move goods to their final destinations. Although personal vehicles outnumber freight vehicles, heavy trucks' fuel economy is much lower than that of personal vehicles, and heavy trucks travel more miles annually on average than personal vehicles travel. These freight travel characteristics result in significant fuel tax revenue from the freight sector. To capture this revenue, the model uses FHWA data to accurately project short haul (single unit) and long haul (combination) truck VMT and fuel economy.

3.4.1 2009 Georgia Freight Vehicle VMT

The model's process for calculating Georgia's 2009 freight VMT relies on the FHWA's HPMS data. This dataset tracks VMT throughout the nation using road network detectors and classifies VMT by vehicle type and road functional class (35). The HPMS database classifies single-unit and combination trucks separately, and this distinction is advantageous for this research, as the vehicle types have different travel behavior and fuel economies (35). This classification is also employed by Agbelie et al. and the Pickrell et al. (24) (37). Table 10 shows the VMT in 2009 traveled on each road type (FHWA functional class) and the percentage of trucks within the entire fleet mix. The model multiplies these two values to calculate the truck VMT per each road type and then sums these to obtain total truck VMT.

Table 10: 2009 Georgia Truck VMT Calculation (35)

Functional Classification	Total VMT (billions)	Single Unit Truck (%)	Combination Truck (%)	Single Unit Truck VMT (billions)	Combination Truck VMT (billions)	Total Truck VMT (billions)
Interstate	31.7	3.00%	18.10%	0.95	5.75	6.71
Arterial	40.5	4.00%	5.30%	1.62	2.15	3.77
Other	36.97	4.10%	2.60%	1.52	0.96	2.48
Total	109.26	3.74%	8.11%	4.09	8.86	12.95

Table 10 shows that the 2009 HPMS truck VMT estimate was just less than 13 billion miles, which is significantly less than the estimated personal VMT of nearly 88 billion miles. The table also indicates that combination trucks drive the majority of freight miles. Combination trucks are more likely on long-haul interstate trips whereas single-unit truck VMT is more likely to occur within urban areas and on arterial streets or local roads to make deliveries. Because the HPMS database, and not household data, was used to predict freight VMT, Table 10's freight VMT data is more credible than the personal VMT produced by the model.

3.4.2 2009 Freight Vehicle Fuel Economy

Unlike personal vehicles, the model does not stratify freight VMT and fuel economy by vehicle model year. Less information exists for fuel economy by truck model year, and less variation exists between the fuel economies of freight model years versus personal vehicle model models years, at least prior to the recent recession and increased fuel prices (41). Fuel economies of 5.5 mpg for combination trucks and 9.0 mpg for single-unit trucks were obtained from a National Research Council report on freight vehicles (41). The U.S. DOT FHWA Highway Statistics webpage states that the estimated 2009 national average fuel economy was 7.4 mpg for single-unit trucks and 6.0 mpg for combination trucks (42). This estimate is based on fuel consumption and VMT data from the HPMS database. The model assumes these values for single-unit and combination trucks for all model years. Separate freight revenue values are calculated from the freight fuel economy of both the National Research Council report and the FHWA Highway Statistics. These revenue streams are presented in Section 3.7.

3.4.3 2009 Georgia Diesel Fuel Price

In order accurately calculate revenue from single-unit and combination trucks, the model needed the average GDOT 2009 fiscal year diesel price. This price was obtained from the U.S. Energy Information Administration's *Petroleum & Other Liquids* database. From this database, the listed weekly diesel price in Georgia was averaged for each week in GDOT's 2009 fiscal year (43). The resulting average came out to be $2.96 (43). The pre-tax diesel price was then calculated by dividing this $2.96 by the state's 4% sales tax on fuel (only 3% contributes toward transportation funding), and then subtracting off the 24.4¢ federal diesel excise tax and the 7.5¢ state excise tax (1). The resulting pre-tax diesel price is $2.54.

3.4.4 2009 Single Unit Truck and Combination Truck Fuel Use

As was mentioned in section 3.4.3, the average gasoline and average diesel price varied significantly in Georgia during GDOT's 2009 fiscal year. To accurately model fuel tax revenue from freight trucks, the model assigned gasoline and diesel consumption for single-unit and freight trucks. The 2002 Vehicle In Use Survey (VIUS) found that of all single-unit trucks, 43.1% consume gasoline and 55.3% consume diesel fuel (44). Of all combination trucks, the survey found that 6.5% of trucks consumed gasoline and 93.3% consume diesel fuel (44). These values were used to distribute the fuel consumed by single-unit and combination trucks into gasoline and diesel categories. The model performs this split in order to more accurately calculate sales tax revenue, as the price of diesel and gasoline varied by 50¢.

3.5 Transit Fleet Revenue Calculation & Methodology

The 2009 transit VMT in Georgia was tabulated using the 2009 National Transit Database (NTD). The Federal Transit Administration (FTA) manages this database and includes operational statistics from each public transit agency in the United States (45). Total bus and/or paratransit gasoline or diesel VMT (compressed natural gas (CNG) vehicles were not included since CNG does not contribute to motor fuels tax revenue) were summed from each public transit agency in Georgia according to the 2009 NTD. Table 11 illustrates this tabulation.

Table 11: 2009 Georgia Transit VMT Tabulation (45)

Transit Agency (Source 2009 National Transit Database)	VMT (thousands)
Hall Area Transit(HAT)	356
Albany Transit System(ATS)	658
Athens Transit System(ATS)	965
Augusta Richmond County Transit Department(APT)	756
Buckhead Community Improvement District(BCID)	20
Chatham Area Transit Authority(CAT)	3,263
City of Rome Transit Department(RTD)	594
Clayton County Board of Commissioners(CTRAN)	1,689
Cobb County Department of Transportation Authority(CCT)	4,764
Douglas County Rideshare(Rideshare)	1,075
Georgia Regional Transportation Authority(GRTA)	4,266
Gwinnett County Board of Commissioners(GCT)	3,609
Macon-Bibb County Transit Authority(MTA)	1,192
Marietta - VPSI, Inc.	4,656
Metra Transit System(Metra)	1,104
Metropolitan Atlanta Rapid Transit Authority(MARTA)	38,356
University of Georgia Transit System(UGA)	723
Total Georgia Transit VMT (thousands)	68,227

From the table, one can see that the total transit VMT in Georgia in 2009 was 68.2 million miles, which is small compared to both personal and freight VMT, which were roughly 88 billion and 13 billion miles, respectively. Nevertheless, the model calculates fuel consumption for transit vehicles using an average fuel economy of 5.5 mpg obtained from the same National Research Council report that provided the fuel economy for the freight vehicles (41). The model calculates transit fuel consumption in the same manner that it calculated personal and freight fuel economy, by dividing transit fuel economy into transit VMT.

3.6 VMT Comparison

Although the primary objective of this research is to model and project motor fuel tax in Georgia, comparing the model's VMT estimate with the estimates provided by the 2009 HPMS serves as an additional validation check. The model used the HPMS database to validate the model VMT estimate. Table 12 shows the model estimated VMT for each fleet subset, Georgia's 2009 HPMS VMT estimate, and the percent difference between the two estimates.

Table 12: Total Estimated VMT per category with comparison against HPMS Estimate

Travel Mode	VMT (billion)
Estimated Personal VMT	87.92
Estimated Single Unit Truck VMT	4.09
Estimated Combination Truck VMT	8.86
Estimated Transit VMT	0.07
Total Model Estimate VMT	100.94
FHWA Estimate (HPMS)	109.25
Percent Difference	7.6%

The table depicts the modeled 2009 Georgia VMT from the personal vehicle, freight, and transit fleets, as well as the total modeled sum of nearly 101 billion VMT. From the table, it is clear that personal vehicle miles drive the majority of Georgia's VMT. The table also indicates that this sum differs by 7.6% from the HPMS estimate of 109.25 billion VMT.

3.6.1 Reasons for VMT Discrepancy

Unfortunately, the discrepancy between the modeled and estimated 2009 VMT in Georgia was 7.6%. Several limitations of the modeling process contribute to this discrepancy, with personal VMT the greatest contributor. As was discussed in section 3.3, the method for estimating personal VMT assumes that only Georgian households contribute to VMT in Georgia, where in fact drivers from other states also drive in Georgia. In addition, the model does not capture VMT from company vehicles, agricultural fuel consumption, or private transit agencies' VMT. In addition, the 2009 NHTS was conducted from April 2008 through April 2009, whereas the FHWA collected the 2009 HPMS data during the 2009 calendar year. This temporal difference contributes to differences in the data. Finally, the HPMS value is an estimate that also contains error. Discrepancies attributed to personal VMT likely represent the greatest error of any of the three categories (personal, freight, transit) in the validation process. Section 3.8 presents an analysis illustrating the effect of the VMT discrepancy on the overall revenue discrepancy.

3.7 Revenue Validation

The final and most important 2009 model comparison is that between the modeled revenue with GDOT's published 2009 FY revenue, a sound foundation is crucial in achieving credible projections. Table 13 on the following page depicts the revenue for each subcategory as well as a comparison with GDOT's publication of its revenue. The table shows that the estimated model revenue is accurate to within less than 3.5% of the published revenue, which implies that the logic used to create the model is acceptable for future revenue projections. The published revenue value came from GDOT's 2009 Funding Report entitled "Investing In Our Future" (46). From the table one can see that revenue from personal VMT accounts for nearly two-thirds of the total revenue and that revenue from freight VMT accounts for nearly one-third of total revenue. In the model, revenue from transit vehicles represents less than 1% of the total revenue.

Table 13: GDOT 2009 Fiscal Year Motor Fuels Tax Revenue Estimate and Comparison with Actual 2009 Fuels Tax Receipts

FY 2009 Personal VMT Receipt Calculation	
Total Fuel Cons (billion gal)	4.21
Total Excise Receipts ($)	$ 316,064,060
Total Sales Tax Receipts ($)	$ 298,238,047
Total Personal Motor Fuels Tax Receipts	$ 614,302,107
FY 2009 Freight Truck Revenue – National Research Council Report Fuel Economies	
Single Unit Truck Fuel Econ (mpg)	9.0
Combination Truck Fuel Econ. (mpg)	5.5
Freight Fuel Consumption (billion gal)	2.07
Excise Tax Revenue	$154,920,104
Sales Tax Revenue	$168,453,410
Total Freight Receipts	$323,373,513
FY 2009 Freight Truck Revenue – FHWA Highway Statistics Fuel Economies	
Single Unit Truck Fuel Econ (mpg)	7.4
Combination Truck Fuel Econ. (mpg)	6.0
Freight Fuel Consumption (billion gal)	2.03
Excise Tax Revenue	$152,218,207
Sales Tax Revenue	$164,843,498
Total Freight Revenue	$317,061,705
FY 2009 Transit Receipts	
Total Transit Fuel Cons (billion gal)	0.012
Excise Tax Revenue	$927,273
Sales Tax Revenue	$831,226
Total Receipts from Transit VMT	$1,758,499
GDOT Published 2009 Fuel Receipts	
$960,000,000.00	
Model 2009 Revenue (National Research Council Fuel Economy)	Percent Difference
$939,425,919.46	-2.14%
Model 2009 Revenue (Highway Statistics Fuel Economy)	Percent Difference
$933,114,110.82	-2.80%

3.7.1 Revenue Discrepancies

There are several reasons for the revenue discrepancies shown in Table 13 in addition to the VMT discrepancies previously discussed in section 3.6. The first and most general is that GDOT operates on a fiscal year beginning July 1; however, many of the inputs used in calculating VMT and fuel economy were based on the 2009 calendar year. Compounding this difficulty is that the economic environment of GDOT's 2009 fiscal year was unique, as both diesel and gasoline prices reached both very high prices (~$4.00/gallon) and relatively low prices (~$1.50/gallon) (40). Diesel prices were also very volatile during this period, as Figure 28 illustrates.

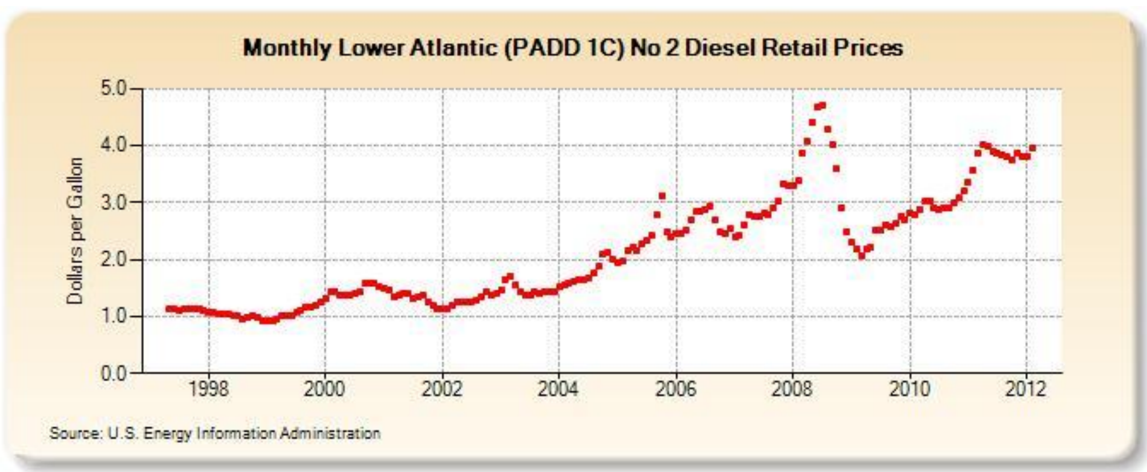


Figure 27: Monthly Diesel Prices for Lower Atlantic 1997-2012 (43)

The nation also entered its most severe economic depression since the 1930s, which changed commuting patterns and driver behavior. The extreme fluctuation in fuel price and the economic turmoil makes compensating for the difference in fiscal and calendar year difficult.

Freight fuel economy accounts for a second reason for the revenue discrepancy in that small adjustments to fuel economies could result in significant fuel tax revenue changes. The magnitude of the impact is high for two reasons. First, is that a single fuel economy value was applied across a relatively high VMT to obtain fuel consumption as compared to the stratified model-year approach employed with personal vehicles. Second is that the fuel economy of freight vehicles is low, and thus any adjustment results in a greater relative percentage than the same absolute adjustment on a higher fuel economy value. Thus, any absolute errors in estimating freight fuel economy will have a greater impact on revenue than would the same absolute magnitude of error in estimating revenue from personal vehicles. The author attempted to counteract this limitation by projecting revenue under multiple freight fuel economy scenarios, as discussed in section 3.4.2 and shown in Table 13. Both sources' fuel economy inputs still result in a projected revenue shortfall as compared to GDOT's published receipts; however, this discrepancy is likely due to the aforementioned VMT differences discussed in section 3.6. Section 3.8 provides a more thorough analysis of the error.

3.8 Model Evaluation & Validation Analysis

The -1.37% and -1.97% differences (depending on the freight fuel economy source) in the model estimate and HPMS estimate shown in Table 12 indicate that the model under-predicts both VMT and fuel tax revenue. However, to properly evaluate the model's ability to predict revenue per VMT, the thesis will assess revenue from corrected VMT. The model calculated personal VMT using NHTS and U.S. Census data, freight VMT using HPMS data, and transit VMT using NTD data. Because the HPMS uses traffic count data, it is believed to be more accurate than the NHTS/Census methodology used to calculate personal VMT. However, because the fuel economies used in the NHTS were obtained from driving activity in Georgia, these values are believed to be the most accurate. To better understand the source of discrepancy in the revenue comparison, personal VMT from the HPMS must be isolated. Table 14 shows this process.

Table 14: HPMS Personal VMT Calculation

Category	VMT (billions)
2009 Georgia state-wide HPMS	109.25
Single-Unit Truck	- 4.09
Combination Truck	8.86
Transit (NTD)	0.068
Resultant HPMS Personal VMT	96.23
NHTS Modeled Personal VMT	87.92

The table indicates that there is a difference of 8.31 billion VMT between the HPMS and model estimates for personal VMT, an 8.64% discrepancy. VMT's effect on the revenue discrepancy is then measured by modeling total 2009 Georgia fuel tax revenue assuming the HPMS personal VMT. This estimate maintains the same VMT distribution by model year and fuel economy assumptions discussed earlier in Chapter 3. Table 15 on the following page presents multiple revenue values using the adjusted VMT values from Table 13 and multiple fuel economies from the National Research Council, FHWA Highway Statistics webpage, and Southworth and Gillett's report on freight performance measures in Georgia (41) (42) (47).

Table 15: Modeled Revenue Assuming HPMS VMT

Source	Revenue	Percent Difference
GDOT Published Revenue	$960,000,000	-
Model Revenue using National Research Council Freight Fuel Economy: 9.0 mpg single-unit trucks; 5.5 mpg combination trucks (41)	$ 997,487,594	3.91%
Model Revenue using Highway Statistics Fuel Economy: 7.4 mpg single-unit trucks; 6.0 mpg combination trucks (42)	$991,175,785	3.25%
Model Revenue using Southworth & Gillett Fuel Economy: 12.6 mpg single-unit trucks; 5.1 mpg combination trucks (47)	$997,764,209	3.93%
Model Revenue using lowest fuel economies from any source: 7.4 mpg single-unit trucks; 5.1 mpg combination trucks	$1,032,342,227	7.54%
Model Revenue using highest fuel economies from any source: 12.6 mpg single-unit trucks; 6.0 mpg combination trucks	$956,597,767	-0.35%

From the table, one can see that the model over-predicts revenue after assuming HPMS VMT values. This means that the model assumes a higher $/mile revenue than actually occurred, if one assumes the HPMS VMT is 100% accurate. The resultant percent differences are vary between -0.35% and 7.54%, depending on which source's or combination of sources' fuel economies one uses. The average error of the three referenced sources is 3.70%. The table indicates that the model revenue more closely approximates the published GDOT revenue with higher freight fuel economies. As was mentioned previously, even slight absolute variations in freight fuel economy can have significant impacts on fuel tax revenue because of the low absolute scale of freight fuel economies. In fact, increasing the single-unit and combination truck fuel economies cited from the Highway Statistics webpage from by less than 1.0 mpg (from 7.4 mpg to 8.4

mpg and 6.0 mpg to 7.0 mpg, respectively) eliminates the entire discrepancy listed in Table 15.

Other reasons for the revenue discrepancy include temporal differences between the databases the model uses, as the 2009 HPMS data is based on the 2009 calendar year, the 2009 NHTS data was collected between April 2008 and April 2009, and the GDOT 2009 fiscal year ran from July 2008 to June 2009 (35) (32) (46). Furthermore, Georgia adjusts its forecasted price only twice a year, on January 1 and June 1, and only changes this price during the six month if the fuel price changes by more than 25% (1). Figure 28 shows the historical price of diesel fuel in the southeast United States and the volatility that occurred in the analysis period.

The temporal discrepancies between the databases make it especially difficult to capture the effects of the unique and rapidly changing economic conditions that occurred during this period. This difficulty, in combination with the aforementioned freight fuel economy sensitivity, likely contributes to the revenue discrepancies seen in Table 15.

The unique economic and pricing conditions observed in 2009 make it a less-than ideal year to serve as a baseline for a projection; however, it also contained the best combination of recent surveys and published data. To help counteract the uncertainties presented by using 2009 as a baseline year, the projection model prompts the user for multiple inputs to quickly observe the effects of different scenarios on fuel prices. Chapter 4 details the methodology of this projection process.

CHAPTER 4

PROJECTION METHODOLOGY

4.1 Model Projection Methodology & Explanation

Chapter 3 defined the model's foundation and validated its logic via comparisons with actual 2009 values. Chapter 4 extends the framework established in Chapter 3 by projecting VMT, fuel economy, and ultimately, motor fuel tax revenue. Despite these extensions, the overall framework remains similar, with the fleet split into personal, fright, and transit categories. The model predicts Georgia's fuel tax revenue in 2009 dollars in the years 2020 and 2030. The author chose 2020 because of a greater availability of cited data with tighter parameters. The author chose 2030 in order to illustrate the effects of vast change in terms of available energy, environmental changes, and technological advancements. The model keeps dollar values constant in order to facilitate comparisons of future revenue with current revenue. The model also incorporates 2009-dollar values for fuel prices and other monetary inputs to eliminate inflation uncertainty.

The projection model uses model-prompted user inputs to provide flexibility in the range of scenarios that the user can input. Users can input more conservative or "business as usual" scenarios which would likely output higher fuel tax revenue, or more aggressive scenarios with higher fuel prices, fuel economies, and electric vehicle market penetrations. This chapter illustrates the model's projection inputs, the thought processes involved in their selection, and the model's ability to serve as a policy tool in predicting revenue under multiple scenarios.

4.2 Personal Fleet Projection Variables & Methodology

The projection model retains all of the 2009 validation model's inputs as well as many that were not present in the validation model. Figure 29 is a graphical framework of these 2009 and projection (new) variables and depicts how they interact to output projected revenue from personal vehicles. As can be seen from the flowchart, household distribution by income cohort, household VMT by income cohort, fuel economy, fuel price, and tax rates are still central components of the framework. However, the model includes new variables such as fleet mix, electric vehicle market penetration and population density to project future fuel consumption and fuel tax revenue. These variables were included based on the literature review described in Chapter 2. The rest of this section discusses the logic and documentation behind each of the variables incorporated in the study's projections.

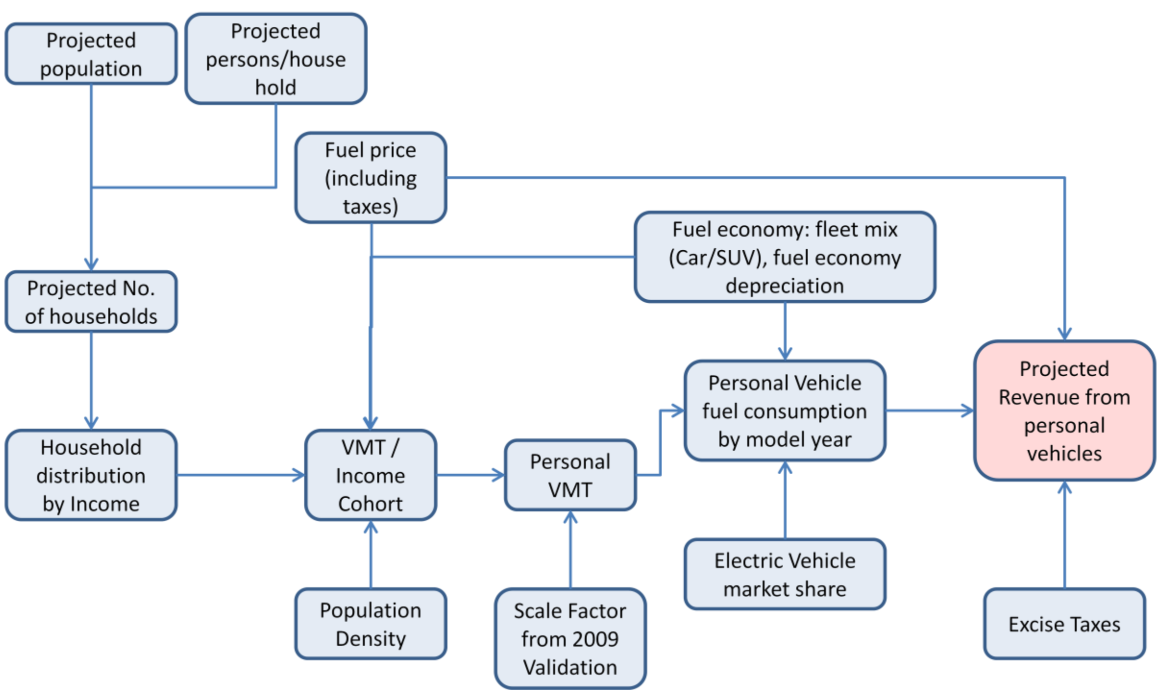


Figure 28: Personal VMT Projection Methodology and Additional Variables

4.2.1 Projected Future Population

Beginning with the upper left-hand corner of the flowchart, future population is an indirect input into the model, as the model relies on the number of households, and not the number of persons in the state. However, total households can be calculated by dividing the average number of persons per household into the total population. Total population data for both 2020 and 2030 was obtained from the ARC's REMI output. This model provides projected population data by race and age from 2010 to 2040 (13). To obtain the total number of statewide households in each of these years, the model uses data from ARC's Plan 2040 to calculate the projected number of persons per household (5). Plan 2040 is specific to the Atlanta region and thus does not provide statewide housing data; however, the model uses these values despite this limitation because they were the most credible estimates available. The model prompts users for their preferred values for both projected population and persons per household. The quotient of dividing persons per household into projected population results in projected households in Georgia for 2020 and 2030. The equation below provides a generic example of how projected persons per household are calculated.

$$Total\ State\ Households = \frac{Projected\ State\ Population\ (REMI)}{Persons\ Per\ Household\ (ARC\ Plan\ 2040)}$$

4.2.2 Projected Household Distribution by Income Cohort

The next input in Figure 29 is household distribution by income cohort. The model incorporates data from the 2009 ACS to generate a distribution of households by income cohort (34). Projecting future wealth distribution is difficult. Because of this, the personal revenue model splits and calculates revenue under two different scenarios. This split is included to allow flexibility and because of data suggesting the size of the nation's middle class is shrinking (48). The first scenario assumes that the income distribution in the projection year (2020 or 2030) remains constant from 2009. The second scenario allows the user to input income distribution percentages (as long as all of the percentages sum to 100) and create their own scenarios. Each scenario assumes the same number of total households using the methodology discussed in the previous sections and allocates households to each income bracket at the input percentages. Table 16 provides an example from the 2020 revenue projection of each scenario and where the model directs the user to input the given alternate household distribution percentages. The orange cells in the table represent the user-input alternative percentages.

Table 16: 2020 Household Distribution by Income Example with 2009 and Alternate Scenarios

Income Classification	**2009 Percentage Scenario**		**Alternative Scenario Percentages**	
Total households	2009 Percents	2009 Cohort	Alternative Percent	Alternative Cohort
Less than $10,000	8.9	404,158	10.0	453,088
$10,000 to $14,999	6.3	285,288	11.0	498,397
$15,000 to $24,999	11.7	528,793	14.0	634,324
$25,000 to $34,999	11.0	500,158	11.0	498,397
$35,000 to $49,999	14.6	659,758	11.0	498,397
$50,000 to $74,999	18.2	825,326	11.0	498,397
$75,000 to $99,999	11.6	526,972	12.0	543,706
$100,000+	17.7	800,429	20.0	906,176

The percentages listed under the "Alternative Percentages" column are example inputs, and they are intended to be adjusted based on the user's desired income distribution. This adjustment allows users to assess how changing income distribution influences future tax revenue.

4.2.3 Projected VMT per Income Cohort

The next input in the personal projection framework (Figure 29) is VMT per income cohort. The 2009 model calculates these values by averaging household VMT per cohort. Although not shown graphically in Figure 29, the model split that began in the income distribution step continues to the VMT per income cohort step. The model splits that assumes a constant 2009 income distribution also assumes a constant 2009 VMT per income cohort in whatever projection year is selected. The alternate branch uses multiple inputs to calculate an alternative VMT per income cohort.

In the alternative calculation, the model assumes that household fuel expenditures remain constant from 2009 up until the projection year for each income cohort; in other words, it “fixes” fuel expenditures. To keep these expenditures constant, the model accounts for three factors: fuel price, fuel economy, and population density. The equation below shows how each of these factors affects future VMT by income cohort.

$$VMT_{Future} = VMT_{2009}\,(\frac{Fuel\ Price_{2009}}{Fuel\ Price_{Future}})(\frac{Fuel\ Economy_{Future}}{Fuel\ Economy_{2009}})$$

$$*\ Population\ Density\ Factor$$

Future fuel price is the pre-tax user input (in 2009 dollars), and the 2009 fuel price is the aforementioned GDOT fiscal year average fuel price of $2.45 per gallon. The model calculates 2009 fuel economy per income cohort in a multi-step process. It first stratifies households by income. It then averages the fuel economy of all of the vehicles in each household that drove at least as much as that household’s average VMT by vehicle. This model needs this process because the NHTS contained many households that owned vehicles with either very low or very high fuel economies that did not record significant annual VMT values. Table 17 on the following page shows the average fuel economy by income cohort from the 2009 NHTS. The table shows that on average, wealthier households own slightly more fuel efficient vehicles. This correlation tends to occur because wealthier families can purchase newer vehicles more frequently, and newer vehicles are, on the average, more fuel-efficient.

Table 17: Average Fuel Economy of Vehicles with Significant VMT in each Household by Income Cohort

Income Level ($)	Fuel Economy of vehicles with VMT greater than their given household's average VMT (cars with greatest usage in their respective households)	NHTS Sample Size per Income Cohort
<10,000	19.98	424
10-15K	20.11	382
15-25K	20.47	771
25-35K	20.59	781
35-50K	21.11	1082
50-75K	21.35	1163
75-100K	21.40	868
100K+	21.39	1051

The model maintains the relationship seen in 2009 between fuel economy and income when projecting future fuel economy by income cohort. The model assumes that on average, wealthier households purchase newer and more fuel-efficient vehicles, while less wealthy households on average will own older and less fuel-efficient vehicles. The model assumed the fuel economy of the wealthiest income cohort ($100,000+) to be the average of the fuel economy of the six newest model years. The model assumed the second wealthiest income cohort owned vehicles between one and eight years old, and each less wealthy income cohort was projected to own older and less fuel efficient vehicles. Table 18 shows the relation between income cohort and the assumed average range of vehicle ownership. These ranges are based on the assumption that wealthier families buy newer, more fuel-efficient vehicles and that less wealthy families own older, less fuel-efficient vehicles at a higher rate. This assumption is based on the data seen in Table 17 and Commuting in America III (16).

Table 18: Household Vehicle Year Model Range Assumption

Income	Household Vehicle Model Year Range
<10,000	3-25
10-15K	3-20
15-25K	3-17
25-35K	3-14
35-50K	3-12
50-75K	2-11
75-100K	1-10
100K+	1-8

The effects of population density were calculated based on a user input and were factored into the projected VMT by income cohort equation through post-processing, that is, after the fuel economy and fuel price component calculations. Section 4.2.5 presents a more detailed explanation of population density's effect on personal VMT.

When looking at the above equation, one can quickly determine that if future fuel price increases faster (relative to 2009 values) than does fuel economy and no population density changes occur, then annual VMT by income cohort will decrease. If fuel economy increases faster than fuel price, then VMT per income cohort will increase. In general, the model assumes that an increasing population density results in fewer annual VMT and a decreasing population density results in greater annual VMT.

4.2.4 Fuel Price

Fuel price is one of the first inputs for which the model prompts. The model prompts the user for the fuel price is 2009 dollars for comparative purposes. The model prompts for a future statewide fuel price, although localized prices will exist throughout the state. In addition, Table 19 shows that the fuel price is input at the price prior to the effect of either the federal excise tax or the state sales and excise taxes, to allow the user to input alternative excise and sales tax rates.

Table 19: Future Fuel Price Entry Example

Total Gasoline Price (all taxes)	$4.28
Gas Price without taxes	$3.90
State Excise Tax / gal	$0.075
Federal Excise Tax / gal	$0.184
Sales Tax %	3%
Diesel Excise Tax/ gal	$0.075

The table shows both the fuel price after all taxes have been applied ($4.28), and the fuel price before taxes being applied ($3.90), which, along with the tax rates, are user inputs. The model prompts for the pre-tax price and the excise and sales tax rates. The EIA's 2011 Outlook predicts gasoline prices, including fuel taxes, of $3.38 in 2020 and $3.64 in 2030 (20). In nominal values, these prices are equivalent to $4.08 and $5.28 per gallon (20). However, this thesis will project revenue under multiple scenarios, as other literature suggests that conventional oil has peaked and that unconventional oil will be both more difficult to extract and more difficult to extract at high quantities. If demand depletes conventional oil faster than expected, fuel prices could reach $4.00+ in 2009-values (49) (29) (3).

4.2.5 Population Density

Population density was included in the model because it was frequently cited throughout the literature review as a factor that affects VMT. Increasing population density often results in not only shorter trips, but also more frequent transit usage, bicycling or walking (25). Each of these behaviors diminishes VMT and motor fuels tax revenue. The model requires the user to input changes in population density with respect to 2009 population density for each income cohort. Thus, for example, one could input different population percentage changes for each income cohort. In order to calculate the effect of change in population density on annual VMT, the model stratifies the 2009 NHTS household database by income. Then, the model plots annual VMT against population density for each cohort. From these plots, lines of best-fit equations were selected depending both on the R^2 value and trend line projection. Table 20 on the following page lists the regression equations for each income cohort as well as the process for calculating the projected change in VMT attributed to change in population density.

The table shows each of the best-fit equations in the right-most column as well as an example of the impact that a 10% increase in population density across each income cohort would have on VMT. This impact is represented by the "0.99," in the "VMT Factor Change" column, meaning that the model predicts that a 10% increase in population density in 2020 would reduce annual VMT across each income cohort by a factor of 0.99. Each change factor value is different but they appear equal because of significant digit limitations. The table also illustrates that the user can enter unique population density changes for each income cohort for both the 2020 and 2030 projections and each change will result in unique impacts on annual VMT by income cohort.

Table 20: Population Density Inputs & Regression Equations by Income Cohort

Income Level ($)	Original Value	2020 Percent Change (User Input)	2020 VMT Change Factor	2030 Percent Change (User Input)	2030 VMT Change Factor	Best Fit Formula
<10K	13,716	10	0.99	0	1.00	y = -1.0431x + 15029
10K-15K	14,722	10	0.99	0	1.00	y = -1956ln(x) + 26192
15K-25K	17,133	10	0.99	0	1.00	y = -1.0584x + 18296
25K-35K	20,941	10	0.99	0	1.00	y = -2466ln(x) + 35554
35K-50K	24,705	10	0.99	0	1.00	y = -2234ln(x) + 38160
50K-75K	28,487	10	0.99	0	1.00	y = -2250ln(x) + 42275
75K-100K	31,710	10	0.99	0	1.00	y = -3072ln(x) + 50425
100K+	36,265	10	0.99	0	1.00	y = -2929ln(x) + 54893

4.2.6 Projected Personal VMT

After each of the flowchart inputs to "Personal VMT" (see Figure 29) have been satisfied, the model then uses the same categorical - proportional technique described in Section 3.3.1 to calculate total projected personal VMT. The model calculates two personal VMT values, one for the 2009 assumptions scenario that assumes a constant 2009 income distribution and constant 2009 annual VMT by income cohort, and another value for the second scenario that allows for a user-input income distribution and fixed fuel expenditures, as discussed in Sections 4.2.2 and 4.2.3 above. The difference between the two VMT projections depends on numerous factors including the user-entered alternate income distribution, projected fuel price, fuel economy, and population density.

The model then multiplies these values by 1.09, which is the ratio of the 2009 HPMS personal VMT to the model personal VMT estimate. This scaling process corrects for the model's tendency to underestimate VMT from personal vehicles and was discussed earlier in section 3.8.

4.2.7 Projected Fuel Economy

Numerous factors affect fuel economy including CAFE standards, market response to fuel prices, technological improvements in manufacturing, and automobile consumer preference due to vehicle characteristics such as horsepower, size and weight. The model uses data from a CAFE standards report that projects yearly lower and upper bound car and light-duty truck fuel economy through 2025 (17). The model extends these projections to 2030 using best-fit regression equations. Table 21 illustrates these values and projections.

Table 21: Lower and Upper Bound Fuel Economy of Cars and Light Duty Trucks 2016-2025 with Regression Extension to 2030 (17)

CAFE Fuel Economy Targets					
Year		Cars		Trucks	
		Lower	Upper	Lower	Upper
2016	1	30.96	41.09	24.74	34.42
2017	2	32.65	43.61	25.09	36.26
2018	3	33.84	45.21	25.2	37.36
2019	4	35.07	46.87	25.25	38.16
2020	5	36.47	48.74	25.25	39.11
2021	6	38.02	50.83	25.25	41.8
2022	7	39.79	53.21	26.29	43.79
2023	8	41.64	55.71	27.53	45.89
2024	9	43.58	58.32	28.83	48.09
2025	10	45.61	61.07	30.19	50.39
2026	11	46.53	62.35	31.70	53.22
2027	12	48.13	64.51	33.52	56.10
2028	13	49.72	66.67	35.55	9.16
2029	14	51.32	68.83	37.80	62.42
2030	15	52.91	70.99	40.26	65.86

After establishing fuel economy projections through 2030, the model averaged upper and lower bound fuel economies for cars and light trucks to obtain a single fuel economy projection for each year. The model prompts the user to enter yearly projected car vs. light truck fleet mix. Because cars have a higher fuel economy than light-duty trucks, the input fleet mix has a significant impact on the overall fuel economy used to calculate fuel consumption. Table 22 provides an example of the model user input.

Table 22: User input Fleet Mix and Resulting Combined Fuel Economy

Year	Light Duty Trucks		Cars		Combined (mpg)
	Fuel Economy (mpg)	Fleet Mix	Fuel Economy (mpg)	Fleet Mix	
2016	29.6	0.35	36.0	0.65	33.8
2017	30.7	0.345	38.1	0.655	35.6
2018	31.3	0.34	39.5	0.66	36.7
2019	31.7	0.335	41.0	0.665	37.9
2020	32.2	0.33	42.6	0.67	39.2
2021	33.5	0.325	44.4	0.675	40.9
2022	35.0	0.32	46.5	0.68	42.8
2023	36.7	0.315	48.7	0.685	44.9
2024	38.5	0.31	51.0	0.69	47.1
2025	40.3	0.305	53.3	0.695	49.4
2026	42.5	0.3	47.0	0.7	45.7
2027	44.8	0.295	56.3	0.705	52.9
2028	47.4	0.29	58.2	0.71	55.1
2029	50.1	0.285	60.1	0.715	57.2
2030	53.1	0.28	61.9	0.72	59.5

The shaded cells in Table 22 are illustrative and do not represent default values. The model structure encourages users to enter a range of values to assess how multiple scenarios impact fuel economy and fuels tax revenue. The model uses the resulting fuel economy outputs in the right-most column of Table 22 as the fuel economy for their respective model year. For example, with the conditions seen in Table 18, the model would use 55.1 mpg as the average fuel economy for all new vehicles purchased and driven in 2028. In addition, because fleet mix is entered as a probability less than one, the model error checks to ensure that the fleet mix values are reasonable.

4.2.7.1 Fuel Economy Depreciation

In addition to the fuel economies derived above, the model includes a fuel economy depreciation factor to account for a vehicle's increased inefficiency as it ages. This model compounds this factor annually and multiplies each year's result by the vehicle's original fuel economy. The default value is 0.985, as this value produces depreciation rates most similar to those found in the literature; however, the GDOT model user may change this in accordance with his or her preference (3).

4.2.7.2 Electric / Alternative Vehicles

The final component of the personal revenue projection is electric vehicle market penetration. While the concept of electric vehicles is nearly a century old, widespread attempts to develop this technology lay dormant until only very recently, as multiple automobile manufacturers are now producing all-electric or plug-in hybrid electric vehicles. A plug-in hybrid electric vehicle is one that has two separate engines: both a conventional liquid fuel (gasoline or diesel) engine and an electric engine powered by batteries that are charged by plugging in the vehicle. An electric vehicle has only an electric engine and no conventional engine. When electric engines power vehicles, drivers purchase less fuel and thus contribute less to motor fuels tax revenue. This is shown, for example, by Vasudevan and Nambisan, who project the percentage of total VMT powered by non-conventional means (36).

The model prompts users to input expected electric vehicle market penetration in the given projection year (2020 or 2030). This projection is entered as a VMT market share, or the percentage of total VMT driven by non-fuel consumption means, and is not based on the number of electric vehicles in the fleet, or fleet market share. The electric vehicle market penetration of years 2012 – 2015 is fixed based on a Center for Automotive Research report (18). The electric vehicle market penetration of the years between 2015 and the given projection year (2020 or 2030) is determined by using linear interpolation from the fixed 2015 value to the user-input projection year input. Figure 30 illustrates the electric vehicle projection process.

Year	2020	2019	2018	2017	2016	2015
Vehicle Age (years)	1	2	3	4	5	6
Percent of Total VMT by Vehicle Age	6.79%	8.81%	7.81%	7.94%	8.33%	7.11%
VMT by Vehicle Age (billion) (2009 VMT/income class)	7.86	10.19	9.03	9.18	9.63	8.22
Percent of Year's VMT by Electric Vehicles	10.00%	8.43%	6.86%	5.29%	3.72%	2.15%
Projected Model Year Fuel Efficiency (2020 mpg-ICE only)	[illegible]8.96	37.61	36.42	35.20	33.37	[illegible]2.16
Fuel Consumption by Year (million gallons)	182	248	231	247	278	250
Excise Tax Receipts ($)	$13,6[illegible]2,926.62	$18,603,347.64	$17,318,744.6[illegible]	$18,531,179.81	$20,850,214.34	$18,7[illegible]9,392.81
Sales Tax Receipts ($)	$31,358,737.77	$42,854,[illegible]71.62	$39,895,460.07	$42,688,425.80	$48,030,55[illegible]75	$43,214,137.28

User-input 2020 Electric-Vehicle Market Penetration

Calculated via linear interpolation from user-input 2020 market share and 2015 Supplemental Report value

2015 Market share percentage from CAFE Supplemental Report

Figure 29: Electric Market Penetration 2020 Example

The figure shows that there is a 10% electric vehicle market penetration in 2020, years 2016-2019 have calculated linearly interpolated market penetrations, and 2015 has a fixed market penetration from the CAFE Supplemental Report (17). The model uses linear rather than exponential interpolation due to the uncertainty associated with future projections; however, PHEV and EV market penetration may increase more rapidly once technology and infrastructure achieves critical mass.

Zhou et al. discuss the impact of charging infrastructure on alternative vehicle adoption rates in their paper presented at the 2012 TRB conference. Based on the data from their research, it is likely that Georgia will be slower to adopt PHEVs and EVs due to the state's relative lack of charging infrastructure (22). Adoption of these vehicles will also depend on battery technology, and the range these vehicles can sustain. Keith et al. also analyze additional factors that affect adoption rates such as manufacturer marketing efforts, social contagion, demographic data (50). They have also developed a flow chart that helps to illustrate the hybrid vehicle adoption process. Figure 31 illustrates this process.

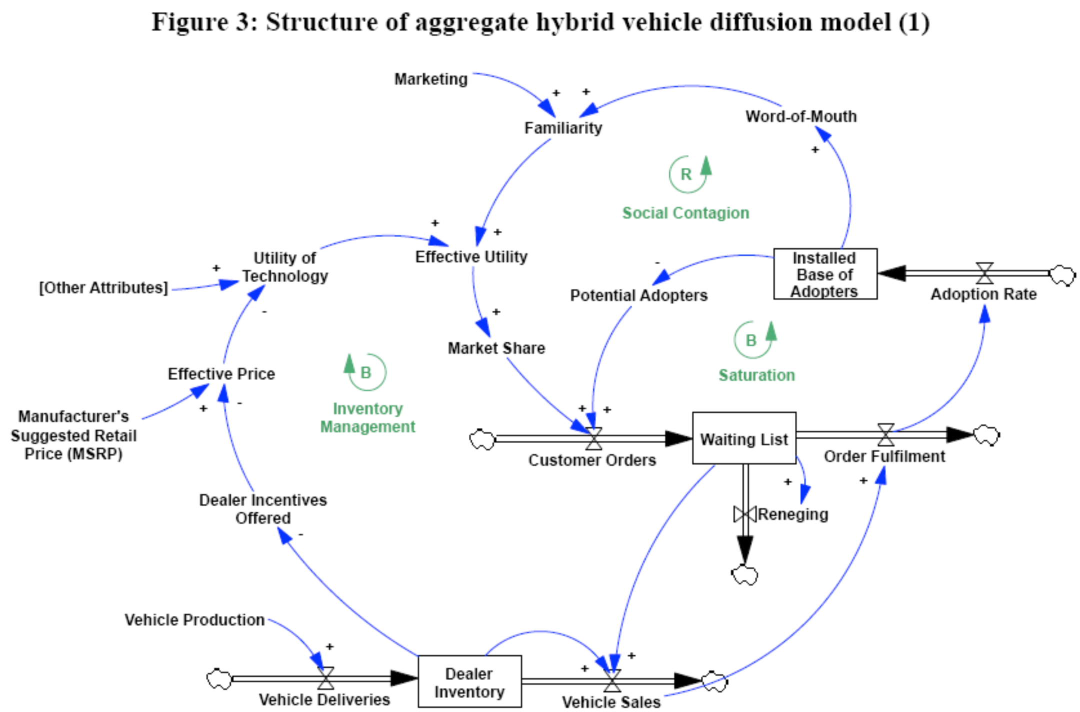


Figure 30: Hybrid/Alternative Vehicle Adoption Flow Chart (50)

In other supporting research, Saphores and Nixon's survey results indicate that users strongly prefer EV technology in cars versus SUVs or trucks. They also found that consumers weight vehicle price, range, refueling time, and fuel cost much more strongly than they do either environmental concerns, U.S. dependence on foreign oil, or technology advancement (51).

4.2.8 Projected Fuel Consumption Methodology

The method for projecting total fuel consumption uses much the same process as estimating 2009 total fuel consumption, albeit with additional variables. As with the 2009 validation, the model distributes total VMT among 25 model years using the same rates observed in the 2009 NHTS; however, the model adds electric vehicle VMT market penetration to this equation, as shown by Figure 29. This is an important addition to the calculation, as the greater the percentage of total miles driven by electric (or non-fuel consuming) vehicles, the less fuel is consumed, thus reducing motor fuels tax revenue, all else being equal. Table 23 illustrates this method (in the table vehicle age increases from right to left but calendar year decreases).

Table 23: Example of Projected Fuel Consumption and Fuels Tax Revenue per Model Year

Year	2020	2019	2018	2017	2016…
Vehicle Age	1	2	3	4	5…
Percent of Total VMT by Veh Age	6.79%	8.81%	7.81%	7.94%	8.33%...
VMT by Vehicle Age (billion) (2009 VMT/income class)	7.80	10.11	8.96	9.12	9.56…
Percent of Year's VMT by Electric Vehicles	10.00%	8.43%	6.86%	5.29%	3.72%...
Model Year Fuel Efficiency (Projected 2020 mpg - ICE only)	39.16	37.30	35.63	33.98	31.79…
Fuel Consumption by Year (million gallons)	179	248	234	254	290…
Excise Tax Receipts ($)	$13,441,049	$18,623,146	$17,573,487	$19,055,670	$21,724,316…
Sales Tax Receipts ($)	$20,640,075	$28,597,703	$26,985,847	$29,261,888	$33,359,860…

The shaded row in the table indicates electric vehicle fleet penetration. The model does not explicitly display its effect on the number of taxable miles or its effect on revenue as the model calculates these within the consumption and revenue calculation cells. The EV percentages in Table 23 are example inputs and are shown only for 5 instead of 25 years due to space limitations.

Each of the aforementioned variables and processes used to project motor fuels tax revenue from personal VMT is based on literature and meant to allow model users the ability to quickly create and adjust multiple scenarios under which they can compare fuels tax revenue. While the model uses numerous inputs, these inputs are not an exhaustive list of all of the factors that could affect future fuel tax revenues from household driving; however, many of these variables such as age and race are correlated with other variables such as income.

4.3 Freight Fleet Projection Variables and Methodology

The freight framework, shown in Figure 32 has fewer inputs than the personal vehicle framework seen in Figure 29. The model uses the FHWA's 2009 HPMS data to project single-unit and combination truck VMT for the given year.

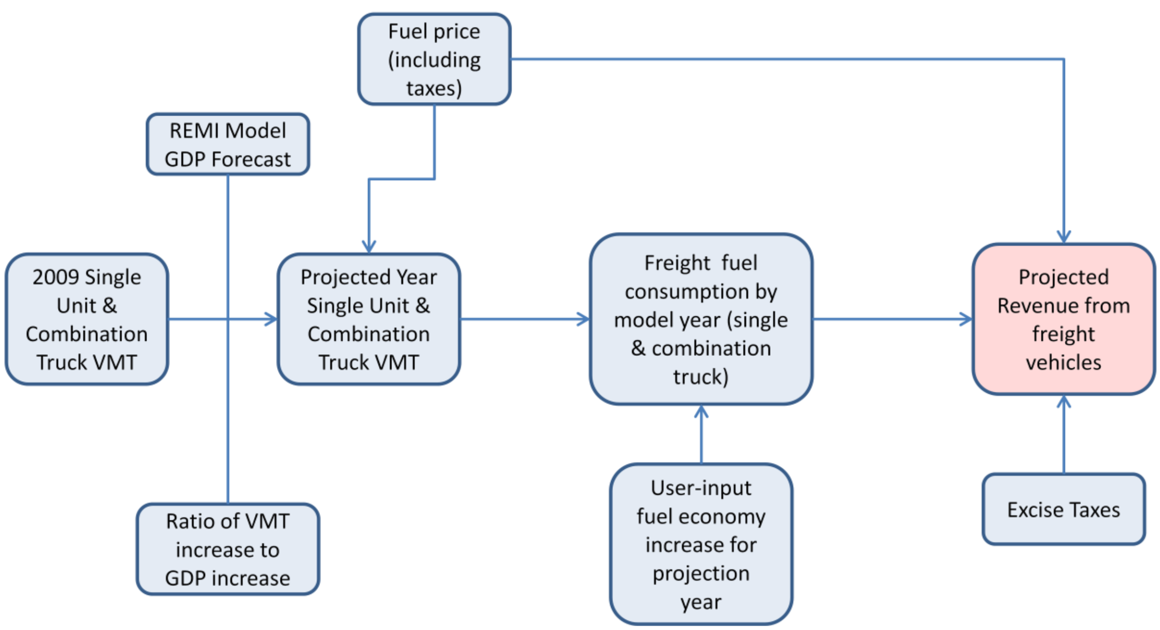


Figure 31: Freight Projection Methodology Flowchart

Figure 32 shows the freight revenue calculation process. As shown, the model distributes the projected freight VMT by truck model year using data from a U.S. Department of Energy report (52). This VMT distribution is similar to the process used in projecting personal VMT discussed in section 4.2. The model projects overall freight VMT projections based on GDP and freight VMT. These GDP predictions are derived from the ARC's REMI (13). The REMI model projects unit-less GDP values from 2009 to 2040, which allows the model user to compare the projected values with the 2009 value. These projections, from year 2009 to 2040, are shown in Table 24.

Table 24: Projected GDP Values: 2009 - 2040 (Source: Atlanta Regional Commission REMI Model)

Year	2009	2010	2011	2012	2013	2014	2015	2016
GDP	230	238	252	268	285	303	323	345
Ratio of YearGDP to 2009 GDP	1.00	1.03	1.10	1.17	1.24	1.32	1.4	1.5
Year	2017	2018	2019	2020	2021	2022	2023	2024
GDP	368	392	418	445	474	506	539	575
Ratio of YearGDP to 2009 GDP	1.6	1.70	1.82	1.93	2.06	2.2	2.34	2.5
Year	2025	2026	2027	2028	2029	2030	2031	2032
GDP	614	655	699	747	798	852	911	973
Ratio of YearGDP to 2009 GDP	2.67	2.85	3.04	3.25	3.47	3.70	4.0	4.2
Year	2033	2034	2035	2036	2037	2038	2039	2040
GDP	1039	1111	1187	1269	1356	1449	1548	1654
Ratio of YearGDP to 2009 GDP	4.52	4.83	5.16	5.52	5.90	6.3	6.73	7.19

4.3.1 Freight VMT Increase Factor

In order to implement GDP-based freight VMT projections, the model needed a solid understanding of the historical relationship between freight activity and GDP. Data from the Bureau of Transportation Statistics (BTS) that contained both freight VMT and GDP in the same database was used to compare how VMT increased with respect to GDP (53). The resulting calculations showed that depending on the time frame and baseline year, VMT increases at a rate of roughly 8%-12% of GDP increase during a time period from 1970 to 2003. The model allows users to input the rate (logically, between 8% and 12%) which they believe freight VMT should increase with respect to GDP in the "Ratio of Freight VMT to GDP change" cell on the 2020 and 2030 projected revenue tabs within the toolbox. This cell and those in Table 24 of the "Future GDP" tab are referenced in the calculation of the freight VMT projection factor. As part of calculating the increase factor, the user-input percentage is multiplied by the percentage increase in GDP from 2009 to the given year. For example:

The 2009 GDP output by REMI was 230 and the 2020 GDP output by REMI was 445 as shown in Table 18. This represents a 93% increase in GDP over this time period (shown by a 1.93 ratio in Table 24). If the model user inputs 10% as the ratio of freight VMT to GDP, then the increase factor applied to freight VMT would be only 1.093.

$$GDP\ Increase\ Factor\colon \left(\frac{445}{230}\right) = 1.93; 0.93 * 0.10 = 0.093; 1 + 0.093 = 1.093$$

This factor represents the multiplicative increase in freight VMT with respect to 2009 resulting from increases in the economy, as measured by GDP. The factor also incorporates fuel price and fuel economy.

The GDOT 2009 fiscal year average diesel price calculated to be $2.96 via the Energy Information Administration's historical pricing database, as was mentioned in section 3.4.3 (43). To project future diesel pricing in either 2020 or 2030, the model prompts users to enter their projected diesel price before price before federal and state taxes. The model then calculates the post-tax diesel price using the user-prompted future tax information. Users also enter their projected increase in freight fuel economy. This process is discussed in section 4.3.3 below.

These fuel costs are a significant component of freight trucking costs. The model factors these into adjusting the aforementioned GDP Increase Factor by incorporating a long-term truck price elasticity. This model uses an elasticity of -0.30, which was derived from Litman's review of long-term freight elasticities (54). The equations below illustrate how user-inputs and the price elasticity equation were used to adjust the aforementioned GDP Increase Factor using future fuel price and freight fuel economy:

$$\varepsilon = \frac{\Delta Q}{\Delta P} x \frac{P}{Q}$$

ΔQ: GDP Increase Factor Adjustment
ε: Long-term freight price elasiticty
Q: Unadjusted GDP Increase Factor
FFP: Future GDOT diesel fuel price
FEI: User-input fuel economy improvement as a percent
IFP: Initial (2009) Fuel Price

The equation will solve for ΔQ, to solve the final GDP Increase Factor, using the following equation:

$$\Delta Q = \varepsilon \; x \; Q \; x \; \left(\frac{\frac{FFP}{FEI} - IFP}{IFP}\right)$$

Thus, using the following sample inputs, the GDP Increase Factor adjustment is calculated:

2009 diesel price (EIA):	$2.96
Example 2020 diesel price (2009 dollars):	$4.20
Example fuel economy increase:	20%
GDP Increase Factor (REMI):	1.093 (see above)
Long-term freight elasticity, ε:	-0.30

$$GDP\ Increase\ Adjustment\ Factor = -0.30\ x\ 1.093\ x \frac{(\$4.20/1.2 - \$2.96)}{2.96}$$

$$= -0.059$$

This adjustment factor (-0.059) is then added to the original GDP Increase Factor (1.093), which results in a final Adjusted GDP Increase Factor of 1.033. Thus, under these conditions, the model projects that both single-unit and combination truck VMT would be 1.033 of their respective 2009 values. These adjustments ensure that the model captures the effects of energy price changes in its output.

4.3.2 Freight VMT Distribution by Model Year

Trucking companies prefer to use the newest and most fuel efficient vehicles possible, and thus the distribution of total truck miles driven is skewed toward newer vehicles with higher fuel economies. Table 25 summarizes the data obtained from a department of energy web page displaying this distribution (52).

Table 25: Freight VMT Distribution Percentage by Truck Model Year (U.S. Department of Energy, 2005)

Vehicle Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Percent of Total VMT (%)	10.9	11.0	10.7	9.5	8.5	7.3	6.6	5.8	4.8	4.6	3.9	3.6	3.1	3.0	2.7	2.7	1.2

Conditions were included within the model that further skewed the table toward the left if the price of gasoline was greater than $4.00 (in 2009 dollars). This adjustment is shown in Table 26, was made because the data used in Table 25 is from 2005, and thus does not show the effects of recent fuel price increases. If fuel prices remain high, trucking companies would invest more heavily in newer vehicles over the long run to capitalize on better fuel economies.

Table 26: Freight Distribution Percentage by Model Year if User-Input Fuel Price is Greater than $4.00

Vehicle Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Percent of Total VMT (If Fuel Price Greater than $4.00)	14	13	12	11	10	8	7	6	4.5	3.5	3.0	2.5	2.5	2.0	1.0	0.0	0.0

Depending on the condition, the percentages from either Table 25 or Table 26 are multiplied by the total projection year freight VMT for single-unit and combination trucks, which was calculated using the Freight VMT Factor. This multiplication results in 17 single-unit and combination truck VMT values, one for each model year. Table 27 shows an example of this multiplication for four of the 17 years that the truck VMT is distributed.

Table 27: Sample Calculation of Single-Unit and Combination Truck VMT for 2030

	2030	2029	2028	2027…
Increase in VMT vs. 2009 (GDP Multiplier)	1.33	1.33	1.33	1.33…
Percent of Total VMT by Truck Model Year	11%	11%	11%	10%...
Single-Unit Truck VMT based on GDP Ratio (billions VMT)	0.59	0.60	0.59	0.52…
Combination Truck VMT based on GDP Ratio (billions VMT)	1.28	1.30	1.27	1.12…

4.3.3 Freight Fuel Economy

Freight fuel economy was determined using 2009 values and a user-input projected increase in freight fuel economy. Less credible projections existed for future truck fuel economies than for personal vehicle fuel economies, and thus the model simply allows the user to specify his or her expected percentage increase in fuel economy in the "Increase in Heavy Truck Fuel Economy" cell in both the 2020 and 2030 projection tabs. This percentage increase is compared to the fuel economy in 2009 and is meant to represent the fuel economy of the model year for that given year (either 2020 or 2030 single-unit or combination truck fuel economy). The model then uses linear interpolation between the projected year and 2009 to calculate the fuel economy of the older model year trucks. Any user-improvements are relative to the 2009 fuel economy of single-unit and combination trucks, estimated to be 9.7 mpg and 5.5 mpg, respectively. These values are the average of the single-unit and combination truck fuel economies provided by the National Research Council Report, Highway Statistics webpage, and Southworth and

Gillett's study on freight performance measures on Georgia, respectively (41) (42) (47). Table 28 shows an example of the fuel economy for each model year based on a projected 25% freight fuel economy increase in 2030.

Table 28: Sample of Projected 2030 Fuel Economies for Single Unit and Combination Trucks based on 25% Increase versus 2009

	2030	2029	2028	2027…
Year_Single Unit Fuel Economy (linear interpolation on 2030 input) --mpg	12.13	12.01	11.89	11.78
Year_Combination Fuel Economy (linear interpolation on 2030 input) --mpg	6.88	6.81	6.68	6.52

Table 28 only shows four model years of truck model years due to page size limitations. Only the fuel economies in the projection year (2030 or 2020) increase by as much as is specified by the user; all other years' fuel economies increase by lesser amounts because the model assumes technologies will not advance as much in earlier years. The model then calculates fuel economy of earlier vehicle model years in the by linear interpolating between the 2009 and the projection year fuel economies.

4.3.4 Freight Fuel Consumption & Revenue

After the model calculates VMT and fuel economy for all 17 model years of freight vehicles, it then calculates the projected fuel consumption for model year by dividing each model year's fuel economy into each model year's VMT for both single-unit and combination trucks. Unlike the revenue derived from personal VMT, gasoline and diesel fuels have different excise taxes and fuel prices. The model applies usage percentages obtained from the 2002 Vehicle In Use Survey to assign single-unit and combination truck fuel consumptions to gasoline and diesel (44). Excise and sales taxes are then calculated for each vehicle's model year with fuel price and fuel consumption data. Table 29 provides sample freight fuel consumption and revenue data.

Table 29: Sample of Projected Fuel Consumption and Fuel Tax Revenue

	2020	2019	2018
Increase in VMT vs. 2009	1.06	1.06	1.06
Percent of Total VMT by Truck Model Year	11%	11%	11%
Single-Unit Truck VMT based on GDP Ratio (billions VMT)	0.47	0.48	0.47
Combination Truck VMT based on GDP Ratio (billions VMT)	1.02	1.04	1.01
Year_Single Unit Fuel Economy (linear interpolation on 2020 input)-mpg	11.43	11.27	10.98
Year_Combination Fuel Economy (linear interpolation on 2020 input)-mpg	6.48	6.39	6.23
Single Unit Truck Fuel Consumption (gallons)	41,230,880	42,413,226	42,406,896
Combination Truck Fuel Consumption (gallons)	157,576,918	162,095,631	162,071,437
Total Truck Excise Tax Receipts ($)	$14,910,584.82	$15,338,164.32	$15,335,874.99
Total Truck Sales Tax Receipts ($)	$19,750,056.98	$20,316,414.34	$20,313,381.98

The model calculates total revenue from freight vehicles by summing the excise and sales tax revenue across each vehicle model year in the projection. The user-inputs impacting revenue include gasoline and diesels prices, VMT to GDP ratio, and fuel economy improvement percentage. The user is encouraged to experiment with how these inputs impact the revenue projections.

4.3.5 Freight Projection Limitations

As with any projection two decades into the future, it is difficult to accurately project freight VMT in 2030. One of the biggest Georgia-specific factors influencing future freight VMT is the expansion of the Port of Savannah. It is yet to be seen how this expansion will affect freight traffic in the state. If the port expands (for example due to more freight coming through the expanded Panama Canal) and diverts traffic from other ports, freight VMT will likely increase at a faster rate than predicted by the model. An expansion would also likely indirectly increase freight VMT due to companies or warehouses relocating to Georgia. Freight VMT in Georgia is also dependent on the infrastructure improvements in other states, as these upgrades could divert freight truck traffic away from Georgia. Finally, revenue from freight VMT also depends on freight's mode split and on rail or water-borne freight increases in market share. A better understanding of this could be developed by comparing infrastructure investments by mode against historical VMT patterns.

Freight fuel economy improvements are dependent on numerous technological factors. The model's predictions are also subject to the accuracy of the estimate of the 2009 single-unit and combination truck fuel economies obtained from the National Research Council, the FHWA's Highway Statistics webpage, and Southworth and Gillett's Georgia freight performance measures study. Although the model averages the values obtained from these three sources because their values varied widely, there is still the potential for inaccuracies.

4.4 Transit Fleet Projection

The transit fleet projection process is simpler than the personal and freight revenue projection processes. In 2009, motor fuels tax revenue from transit represented such a small percentage of overall fuel tax revenue that it would take a 70-fold increase in transit VMT by 2020 for motor fuels tax revenue from transit to account for even 10% of total motor fuels tax revenue. Because of this, the model prompts the user to input a projected multiplicative increase in transit VMT in the "Factor to Increase Transit VMT vs. 2009" cell in the 2020 and 2030 tabs. This model multiplies this factor by the transit VMT in Georgia estimated in 2009.

The model also allows users to input their projected increase in transit fuel economy from the 2009 value of 5.5 mpg in both the 2020 and 2030 projection tabs. The model then calculates projected fuel consumption from the transit VMT and fuel economy projections. It then calculates transit fuel tax revenues via the fuel consumption quantity and the user-input fuel price. Table 30 provides an example of this calculation.

Table 30: Sample Transit Calculation for 2020

Projected 2020 Transit Receipt Calculation (2009 Dollars)	
Total Transit VMT (billion VMT)	0.68
Average Transit Fuel Econ (mpg)	6.6
Total Transit Fuel Cons (billion gal)	0.103
Excise Tax Revenue	$7,727,272.73
Sales Tax Revenue	$11,272,700.00
Total Receipts from Transit VMT	$18,999,972.73

The values in Table 30 are based on user-inputs of a 10-fold increase in transit VMT and a 20% increase in transit fuel economy. Even with this 10-fold increase, the total motor fuels tax revenue is only approximately $19 million, which is small (just over 1%) compared to the nearly $1.2 billion in total revenue projected to be collected from all sources. Even if gas prices rise, population density increases dramatically, and transit becomes more user-friendly in Georgia, it is unlikely that transit will be a significant source of motor fuels tax revenue for GDOT in the next two decades.

In summary, this model prompts the user for multiple inputs, allowing them to observe how different input scenarios affect Georgia's motor fuel tax revenue in 2020 and 2030. Selected model results are presented in Chapter 5.

CHAPTER 5 MODEL RESULTS

The methodologies discussed in Chapter 4 were used to project motor fuel tax revenue in Georgia in 2020 and 2030. The model does not adjust the revenue for inflation and outputs values in 2009 dollars in order to facilitate easier comparisons with recent revenues. This chapter includes conservative and aggressive revenue projections for 2020 and 2030. The conservative scenario assumes more business-as-usual inputs that result in higher fuel tax revenues. The aggressive scenario assumes higher fuel prices with higher vehicle fuel economies and electric vehicle market penetrations in response.

5.1 2020 Results

The author selected 2020 as a projection year for multiple reasons. First, this eight year projection period is short enough that credible, state-level projections exist for multiple variables. Second, this forecast is short enough that it could directly impact Georgia transportation agencies' long-term capital projects. However, there is still much uncertainty associated with this projection, as fuel prices, technologies, and economic conditions could still change drastically during this period. The model attempts to counter this uncertainty by prompting users for multiple inputs and allowing them to observe multiple revenue scenarios quickly.

5.1.1 2020 Conservative Scenario Results

This scenario assumes lower fuel prices with fewer technology advancements and travel behavior changes. The model assumes a fuel price (in 2009 dollars) of $3.38, based on the EIA's projections in its 2035 Outlook report (20). Based on current discrepancies between diesel and gasoline prices, it assumes a $3.60 diesel price in 2020

(43). It also assumes a 1.5% annual growth in freight and transit fuel economies, which results in a total fuel economy improvement of 17.8% versus 2009 values. To project personal fuel economies, the model utilizes data from the CAFE Standards Supplemental Report in combination with user input fleet mix percentages. The conservative model assumes a 50% car vs. 50% light-truck split through 2020 based on 2010 new vehicle sales (55). Conservatively, the model assumes that PHEV's or EV's will drive only 5% of all VMT. The model also assumes the listed population and persons/household values obtained from ARC's REMI and Plan 2040 respectively. Other demographic assumptions include a 5% increase in population density while maintaining a constant income distribution from 2009. Lastly, the model assumes a default freight VMT/GDP ratio of 0.10 and a fuel economy depreciation factor of 0.985 as discussed in section 4.3. Table 31 on the following page shows these inputs and the corresponding results.

Table 31: 2020 Conservative Scenario Inputs & Revenue Output

2020 Conservative Scenario Input Variables (All prices in 2009 $)			
Gasoline Price after taxes	$3.38		
Gasoline Price before taxes	$3.02		
State Excise Tax / gal	$0.075		
Federal Excise Tax / gal	$0.184		
Federal Diesel Excise Tax/ gal	$0.244		
State Sales Tax %	3%		
Diesel Price after taxes	$3.60		
Diesel Price before taxes	$3.13		
Diesel Excise Tax/ gal	$0.075		
Diesel Sales Tax %	3%		
Ratio of Freight VMT to GDP change	0.10		
Increase in Freight Fuel Economy from 2009 to 2020 (%)	17.8		
Factor to Increase Transit VMT vs. 2009 Transit VMT	5		
Increase in Transit Fuel Economy from 2009 to 2020 (%)	17.8		
Fuel Efficiency Depreciation Rate (Compounded Annually and Multiplied by Original Rate)	0.985		
Electric vehicle market share as a percentage of 2020 vehicle sales	5		
Persons per Household	2.72		
		Per capita Revenue	Per capita % difference vs. 2009
Predicted 2020 fuels tax revenue using 2009 Income & VMT distribution	$1,150,079,087	$93.32	-5.71
Actual 2009 Georgia Fuel Tax Revenue	$960,000,000	$98.87	

The table indicates that motor fuel tax revenue could be nearly 200 million real dollars higher in 2020 versus 2009's revenue if demographic and environmental conditions are business as usual in terms of historical growth and change. This revenue increase over eleven years is equivalent to an annual growth rate of 1.65%. On a per-capita basis, the projected 2020 revenue is 5.71% less than 2009's per capita value. The significant increase in revenue between 2009 and 2020 is driven largely by population growth and increases in economic activity as indicated by GDP.

5.1.2 2020 Aggressive Scenario Results

The 2020 aggressive scenario modifies the values discussed in section 5.1.1 to create a scenario indicative of greater technological advancements and behavioral changes. These modifications were made by modifying referenced percentages and choosing the more aggressive values cited in literature. For example, the model assumes 15% higher fuel prices than suggested by the EIA's 2011 projections, which equates to a gasoline price of $3.88 and a diesel price of $4.08. In terms of vehicle improvements, it presumes a 1.75% annual growth in the fuel economy of single-unit trucks, combination trucks, and transit vehicles, which results in a fuel economy improvement of over 21% versus 2009 values, and that PHEV's or EV's will drive 10% of all VMT in 2020. It also assumes population density changes of 15% in lower income cohorts and 10% in higher income cohorts and increases the listed persons/household value by 1%. The aggressive scenario also incorporates predictions about a declining middle class in terms of income distribution. Finally, it assumes a linearly increasing percentage of cars in the fleet per model year, beginning at 50% in 2012 and ending at 65% in 2020. Table 32 on the following page shows these inputs and corresponding revenue output.

Table 32: 2020 Aggressive Scenario Inputs & Revenue Output

2020 Aggressive Scenario Input Variables (All prices in 2009 $)			
Gasoline Price after taxes	$3.88		
Gasoline Price before taxes	$3.51		
State Excise Tax / gal	$0.075		
Federal Excise Tax / gal	$0.184		
Federal Diesel Excise Tax/ gal	$0.244		
State Sales Tax %	3%		
Diesel Price after taxes	$4.08		
Diesel Price before taxes	$3.64		
Diesel Excise Tax/ gal	$0.075		
Diesel Sales Tax %	3%		
Ratio of Freight VMT to GDP change	0.10		
Increase in Freight Fuel Economy from 2009 to 2020 (%)	21		
Factor to Increase Transit VMT vs. 2009 Transit VMT	5		
Increase in Transit Fuel Economy from 2009 to 2020 (%)	21		
Fuel Efficiency Depreciation Rate (Compounded Annually and Multiplied by Original Rate)	0.985		
Electric vehicle market share as a percentage of 2020 vehicle sales	10		
Persons per Household	2.75		
		Per capita Revenue	Per capita percent difference vs. 2009
Predicted 2020 fuel tax revenue using alternate Income & VMT distribution	$1,166,148,076	$92.25	-4.39
Actual 2009 Georgia Fuel Tax Revenue	$960,000,000	$94.62	

Although this is the more aggressive of the two scenarios, it actually results in more revenue and projects more than 200 million real dollars more in revenue than GDOT received in 2009. This translates to an annual growth rate of 1.78% since 2009. On a per-capita basis, the projected 2020 aggressive scenario is 4.39% lower than the actual 2009 per capita receipts. Despite increases in variables that typically result in decreased fuel consumption such as fuel economy, electric vehicle market penetration, population density, and persons per household, the increase in the gasoline and diesel prices actually increases the overall revenue. Many sources in the literature noted the inverse correlation between fuel price and travel, which would prompt one to believe that a more aggressive or higher fuel price would reduce fuel tax revenue via reduced fuel consumption. However, the sales tax component of Georgia's fuel tax structure means that the higher fuel price results in greater revenue per gallon. Thus, even with fewer gallons purchased, the above scenario results in more total fuel tax revenue as compared to the conservative scenario due to the comparatively higher fuel prices.

Both of the 2020 scenarios project significant fuel tax increases compared to 2009 revenue, driven largely by population growth and increases in freight activity. Due to the sales tax component of Georgia's fuel tax structure, the higher fuel prices in the aggressive scenario results in higher revenue than output the conservative scenario despite lower fuel consumption.

5.2 2030 Results

The 2030 revenue projections contain more uncertain than the 2020 predictions because more time will have elapsed for technologies to advance, for energy resources to change, and for driver behavior to adapt. As with the 2020 scenarios, this thesis presents a conservative scenario and an aggressive scenario as part of the results.

5.2.1 2030 Conservative Scenario Results

As with the 2020 conservative scenario, the 2030 conservative scenario adopts many inputs from recent literature. The projected 2030 gasoline and diesel prices in 2009 dollars are \$3.64 and \$3.85 respectively, as provided by the EIA's 2011 Outlook (20) and current gasoline diesel relationships (43). This scenario assumes a 1.5% annual fuel economy improvement from 2009 to 2020 and then a 1.0% annual improvement from

2020 to 2030 for single-unit trucks, combination trucks, and transit vehicles. This results in a 30% fuel economy improvement in 2030 versus 2009. A car fleet percentage of 55%, a light-truck percentage of 45%, and a 10% PHEV/EV market penetration value were also presumed. Demographically, the scenario assumes the population and persons per household values obtained from REMI and ARC's Plan 2040, a population density increase of 10% across all cohorts, and a constant income distribution from 2009 values. Table 33 shows the 2030 conservative scenario inputs and resulting output.

Table 33: 2030 Conservative Scenario Inputs and Revenue Output

2030 Conservative Scenario Input / Output Variables (All prices in 2009 $)			
Total Gasoline Price (all taxes)	$3.65		
Gas Price before taxes	$3.28		
State Excise Tax / gal	$0.075		
Gasoline Sales Tax %	3%		
Federal Excise Tax / gal	$0.184		
Federal Diesel Excise Tax /gal	$0.244		
Diesel Price After Taxes	$3.85		
Diesel Price Before Taxes	$3.42		
Diesel Excise Tax/ gal	$0.075		
Diesel Sales Tax %	3%		
Ratio of Freight VMT to GDP	0.10		
Increase in Heavy Truck Fuel Economy from 2009 to 2030 (%)	30		
Factor to Increase Transit VMT from 2009	10		
Increase in Transit Fuel Economy from 2009 to 2030 (%)	30		
Annual Compounded Fuel Efficiency Depreciation Rate	0.985		
Electric vehicle market share as a percentage of 2030 vehicle sales	10		
Persons / Household	2.67		
		Per Capita Revenue	Per capita difference vs. 2009
Predicted 2030 fuels tax revenue using 2009 Income & VMT distribution	$1,078,067,602	$77.58	-21.61%
Actual 2009 Motor Fuel Tax Revenue	$960,000,000	$98.97	

The table displays the significant decline in per-capita revenue that the 2030 conservative scenario projects. The projected revenue (in 2009 dollars) of approximately $1.08 billion dollars is approximately $120 million real dollars greater than the actual GDOT 2009 FY revenue. It also means that the projected 2030 conservative scenario revenue is actually $70 million less than the projected 2020 conservative scenario's projected revenue output. This means that the increases in fuel economy, population density, and electric vehicle market penetration outweighed the increases in population growth and freight activity. Specifically, fuel economy improvements and changes in variables decreasing fuel tax revenue increased much more rapidly than did those variables increasing fuel tax revenue between 2020 and 2030.

5.2.2 2030 Aggressive Scenario Results

As with the 2020 aggressive scenario, the 2030 aggressive scenario departs from many of the referenced values by percentage-based adjustments. The model assumes the fuel price is 15% higher than published in the EIA's 2011 report. This increase results in a gasoline price of $4.19 in 2009 dollars and a diesel price of $4.39 after taxes based on current relationships between gasoline and diesel prices (43). The aggressive model also assumes more extensive technology advancement in freight truck and transit fuel economy, with an annual fuel economy improvement of 1.5% from 2009 to 2030, which results in a 37% improvement over 2009 fuel economies. Other vehicle inputs for the aggressive model include a linearly increasing percentage of new car sales, beginning with 50% in 2012 and 70% in 2030, and that 30% of all VMT will be driven by either PHEVs or EVs. Demographically, the model assumes a 5% higher persons/household value than published by ARC's Plan 2040, a 25% population density increase for lower income cohorts and a 15% population density increase for wealthier income cohorts. It also assumes an alternative wealth distribution with a smaller middle class. Table 34 shows the 2030 aggressive scenario inputs and resulting output.

Table 34: 2030 Aggressive Scenario Input and Revenue Outputs

2030 Aggressive Scenario Input / Output Variables (All prices in 2009 $)			
Total Gasoline Price (all taxes)	$4.19		
Gas Price before taxes	$3.81		
State Excise Tax / gal	$0.075		
Gasoline Sales Tax %	3%		
Federal Excise Tax / gal	$0.184		
Federal Diesel Excise Tax /gal	$0.244		
Diesel Price After Taxes	$4.39		
Diesel Price Before Taxes	$3.94		
Diesel Excise Tax/ gal	$0.075		
Diesel Sales Tax %	3%		
Ratio of Freight VMT to GDP	0.09		
Increase in Heavy Truck Fuel Economy from 2009 to 2030 (%)	37		
Factor to Increase Transit VMT from 2009	15		
Increase in Transit Fuel Economy from 2009 to 2030 (%)	37		
Annual Compounded Fuel Efficiency Depreciation Rate	0.985		
Electric vehicle market share as a percentage of 2030 vehicle sales	30		
		Per Capita Revenue	Per capita difference vs. 2009
Predicted 2020 fuel tax revenue using alternate Income & VMT distribution	$1,063,436,883	$76.49	-22.71%
Actual 2009 Motor Fuel Tax Revenue	$960,000,000	$98.97	

The 2030 aggressive scenario projects $15 million dollars less revenue than did the 2030 conservative scenario, which results in nearly a 23% decrease in per-capita revenue. This projected revenue is only $100 million real dollars greater than GDOT's actual 2009 FY revenue. These declines are due to the increases in fuel economy and significant (30%) electric vehicle market penetration by 2030. Population density increases and alternative distributions of household wealth also contribute to a revenue decline. Because of the sales tax, the aggressive scenario's relatively higher fuel prices do not decrease the fuel tax revenue as could have occurred.

5.3 Scenario Comparison

Table 35 compares the revenue output of each of the four projection scenarios in addition to that of the 2009 actual revenue.

Table 35: Scenario Revenue Comparison Matrix

Scenario	VTM (billions)	Total Revenue (millions $)	Per-Mile Revenue (¢/mi)	Per-Capita Revenue
2009 Actual	109.25	$960	0.88	$98.97
2020 Conservative	140.03	$1,150	0.82	$93.32
2020 Aggressive	125.04	$1,166	0.93	$94.62
2030 Conservative	161.56	$1,079	0.67	$77.58
2030 Aggressive	156.22	$1,063	0.68	$76.49

Both of the 2030 scenarios have significantly lower absolute, per-mile, and per-capita revenue than the 2020 scenarios. When comparing within each year, the aggressive scenario projects higher revenue in 2020 due to the sales tax contribution from higher fuel prices, but in 2030, the conservative scenario projects more revenue due to the high fuel economy and electric vehicle market penetrations in the aggressive scenario. In terms of VMT, there is greater variation between the 2020 scenarios than between the 2030 scenarios. This discrepancy is driven by VMT from personal vehicles, as the fuel price is projected to increase more than vehicle fuel economy by 2020, which causes personal VMT to decline significantly in the 2020 aggressive scenario. This VMT discrepancy leads to a significant difference in per-mile revenue between the two 2020 scenarios as well. From a policy perspective, Table 35 indicates that GDOT will gain revenue through 2020, but will then e lose funding on an absolute basis during the next decade. This means that GDOT has time to plan thoroughly for a supplement or replacement to the motor fuel tax before fuel economy improvements and alternative vehicles erode its revenue.

5.4 VMT Consumption Validation

Attempts were made to validate the model's projections with independent projections. Few credible sources exist that project VMT or fuel consumption on a state-by-state basis; however, one can take steps to modify national-level projections. One method of validating the projected VMT is to use national level VMT projections in conjunction with a ratio comparing Georgia's projected population growth with the nation's projected population growth. Table 36 shows the EIA's projected national VMT growth through 2030 from their Annual Energy Outlook (56).

Table 36: Projected National VMT Growth & Annual Growth Rate (2009 - 2030) (56)

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Projected U.S. VMT	2,981	3,017	3,054	3,113	3,177	3,224	3,278	3,339	3,394	3,446	3,497
Projected Growth Rate	N/A	1.2%	1.2%	1.9%	2.1%	1.5%	1.7%	1.9%	1.7%	1.5%	1.5%
Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Projected U.S. VMT	3,555	3,618	3,674	3,734	3,789	3,851	3,913	3,973	4,037	4,095	4,166
Projected Growth Rate	1.7%	1.8%	1.6%	1.6%	1.5%	1.6%	1.6%	1.5%	1.6%	1.5%	1.7%

Because Georgia's future population growth may not match the projected national population growth, the annual growth rates from ARC's REMI population projections were compared with the annual growth rates from the U.S. Census' national population projections. The U.S. Census average annual national population growth rate through

2030 was 0.92%, while the REMI average growth rate for Georgia through 2030 was 1.29% (57) (13). The ratio of these values is calculated in the equation below:

$$Georgia: U.S. Population\ Growth\ Ratio = \frac{1.29\%}{0.92\%} = 1.40$$

This ratio was multiplied by the national annual VMT growth rates seen in Table 36. The products of the Growth Ratio (1.40) and the annual growth rates was then applied to HPMS estimate of Georgia's 2009 VMT of 109.25 billion miles traveled. Table 37 shows Georgia's projected VMT using the adjusted and unadjusted annual growth rates, highlighting the projected 2020 and 2030 VMT values.

Table 37: Projected Georgia VMT Using U.S. VMT Growth Rate & Adjusted Rate by Population Ratio

Year	2009	2010	2011	2012	2013	2014	2015	
Projected VMT (U.S. aggregate increase)	109.3	110.6	111.9	114.1	116.4	118.1	120.1	
Projected VMT (Adjusted increase)	109.3	111.1	113.0	116.0	119.4	121.9	124.7	
Year	2016	2017	2018	2019	2020	2021	2022	
Projected VMT (U.S. aggregate increase)	122.3	124.4	126.3	128.1	130.3	132.6	134.6	
Projected VMT (Adjusted increase)	128.0	130.9	133.8	136.5	139.7	143.2	146.3	
Year	2023	2024	2025	2026	2027	2028	2029	2030
Projected VMT (U.S. aggregate increase)	136.8	138.8	141.1	143.4	145.6	147.9	150.1	152.7
Projected VMT (Adjusted increase)	149.6	152.7	156.2	159.7	163.2	166.9	170.3	174.4

The table illustrates a range of VMT predictions for Georgia based on the EIA's national VMT prediction growth rates and an adjusted growth rate that uses Georgia's and the United States' projected population growth. Due to uncertainty, this range is wider in 2030 than in 2020. Table 38 on the following page compares the projected VMT values from each year's scenarios with the VMT validation projections from Table 37 above.

Table 38: VMT Validation Comparison

Scenario	2020	2030
Projected (U.S. Growth Aggregate Increase)	130.30	152.70
Aggressive	125.04	156.22
Conservative	140.03	161.56
Projected (Adj. Increase)	139.70	174.40

Table 38 shows that the 2020 scenarios' VMT projections fall just outside of the independent projection method's VMT values, while each of the 2030 scenarios' VMT predictions are solidly within the validation's projection bounds. The 2020 aggressive scenario's VMT is 4.6% below the 2020 U.S. growth rate VMT projection and the 2020 conservative scenario is 0.2% above the 2020 Adjusted Growth Rate scenario. Increases in fuel price and population density, alternative income distribution with less middle class, and increased persons per household value all reduce VMT within the model. The relative proximity of the 2020 and 2030 scenarios' VMT values to those projected by the validation technique suggest the reasonableness of the projections generated by the thesis. However, this validation exercise does have some limitations.

5.4.1 Validation Limitations

Validation for other variables (i.e. fuel consumption, revenue) is largely dependent on VMT, fuel economy, and fuel price. Section 5.3 described the VMT validation process and showed that the VMT projections presented in the scenarios in sections 5.1 and 5.2 are within at most 4.6% percent of the validation methodology's VMT value. Validating fuel consumption with an independent process necessitates independent VMT and fuel economy sources. However, the thesis model already includes fuel economy from government agencies (17). Although these fuel economy projections involve uncertainty, they are as credible as any other projection. Because of this, manufacturing an independent fuel consumption value to validate the model's fuel consumptions values is difficult. Consequently, creating an independent revenue projection faces the same difficulties because fuel tax revenue is largely based on fuel consumption quantities. Fuel prices are another uncertainty in the revenue projection process, and as the last few years have illustrated, gasoline and diesel prices can be volatile in the short-run. Furthermore, increasing automobile ownership in countries like China and India, and continued instability in the oil-exporting Middle East will likely increase this volatility (3).

CHAPTER 6 ALTERNATIVE REVENUE MECHANISMS

The revenue projections in Chapter 5 illustrate the potential for a decrease in the growth of real fuel tax revenue in Georgia, especially between 2020 and 2030. These projections are on top of the fact that current federal level spending on highway and transit as a percentage of GDP has already fallen by more than 25% since the establishment of the Highway Trust Fund in the 1950s (58). This decline has occurred in spite of market share growth of SUVs and light-duty trucks, as the national average fuel economy has increased from 13.9 mpg in 1975 to 22.8 mpg in 2008 (59). While the exact dollar values of the thesis' projections entail significant uncertainty, the overall trends of increasing VMT and fuel economy are more certain due to increasing population and mandated CAFE standards. Vasudevan and Nambisan project that fuel tax revenue could be reduced by 21% by 2025 from increases in fuel economy alone (36). In conjunction with a likely decrease in per-capita and per-mile fuel tax revenue, the increase in VMT and congestion on the state's roads, railroads, ports, and airports will likely result in increased operation and maintenance expenditures. This increase necessitates increased revenue to maintain a balanced budget.

A number of strategies could facilitate increasing revenue, including increasing the current motor fuel tax or indexing it to inflation. The state could also enact other supplemental or replacement revenue mechanisms to gain additional revenue. These mechanisms include a distance-based or VMT-fee, widespread tolled or high occupancy toll (HOT) lanes, and other measures. This chapter discusses briefly the benefits and drawbacks of these methods and provides a basic pricing structure and sensitivity assessment for some of them.

6.1 Fuel Tax Modification

Increasing the motor fuel tax is an obvious method of increasing fuel tax revenue, as the state's excise and sales taxes have not been increased since 1971 (60). This increase would result in immediately revenue gains for GDOT. In the short run, these revenue gains could cover the revenue shortfalls transportation agencies face in maintaining their infrastructure and assets (58). The fuel tax could be increased via an absolute increase (i.e. 5¢), by linking the tax to inflation, or both.

6.1.1 Excise Tax Increase

Because Georgia's motor fuel tax has both excise and sales tax components, GDOT would have options if they wanted to raise motor fuel tax revenue. At $4.00 per gallon, a 1% increase in the sales tax percentage would be equivalent to a 12¢ excise tax increase. Because sales tax is linked to fuel prices, and because many sources project real long-term fuel prices to increase, both the general public and politicians might be less receptive to a sales tax increase. This analysis will instead focus on 5¢ and 10¢ increases to the excise tax using the 2020 and 2030 scenarios discussed in Chapter 5 to make comparisons. These comparisons maintain the same inputs from their respective scenarios. Table 39 shows the revenue gains that excise tax increases could provide.

Table 39: Revenue Gains (in millions of dollars) from Excise Tax Increases

Scenario	Original Revenue	Gain From +5¢ Tax	Gain from +10¢ Tax
2009 Actual	$960	N/a	N/a
2020 Conservative	$1,150	$337	$672
2020 Aggressive	$1,166	$302	$598
2030 Conservative	$1,079	$301	$602
2030 Aggressive	$1,063	$299	$572

The table shows that even modest increases to the motor fuel tax could produce significant revenue gains for Georgia over the next two decades. The model makes these projections by changing the fuel tax values within the model so that the elasticities and other interactions built into the model would take into account these changes. The table indicates that the model predicts greater revenue increases from a modified excise tax in the 2020 scenarios than in the 2030 scenarios due to the aforementioned fuel economy improvements and increased electrical vehicle sales slated to occur between 2020 and 2030. The table also shows greater revenue increases in the conservative scenarios than in the aggressive scenarios. The values in the table are real 2009 values, and thus are not affected by inflation. However, construction costs will likely increase with inflation during this period. The additional revenue produced by linking the excise tax increases to inflation is discussed below.

6.1.2 Indexing Fuel Tax to Inflation

Another method of increasing motor fuel taxes is to link the excise tax to inflation after an initial increase. The initial increase would help to pay for immediate infrastructure and maintenance needs, while linking to inflation would help to maintain the purchasing power of the revenue stream over the long-run. According to the U.S. Bureau of Labor and Statistics, the average annual inflation in the United States over the last 10 years was 2.53% (61). Comparisons to the revenues from the scenarios presented in Chapter 5 will be made using a initial 5¢ increase to the state excise tax (in 2012) and then increasing the new excise tax by 2.53% annually through 2030. This annual increase produces a 2020 excise tax of 15¢/gallon and a 2030 excise tax of 19¢/gallon. Table 40 displays the results of these outputs.

Table 40: Revenue Gains (in millions of dollars) from Initial 5c Tax Increase and Link to Inflation

Scenario	Original Revenue	Gain from +5c Tax & Indexing to Inflation
2009 Actual	$960	N/A
2020 Conservative	$1,150	$1,007
2020 Aggressive	$1,166	$888
2030 Conservative	$1,079	$1,141
2030 Aggressive	$1,063	$1,002

These results indicate that linking the excise tax to inflation after an initial increase results in greater revenue than either a 5¢ or 10¢ flat increase, which in many cases nearly doubles or more than doubles the original scenario's revenue. Because the tax grows each year at the 2.3% inflation rate, the 2030 revenue is greater than the 2020 revenue, despite the higher fuel economy and presence of electric vehicles. The table shows that while linking the excise tax to inflation would generate more revenue than a 5¢ or 10¢ flat tax, fuel economy improvements and electric vehicle market penetrations cause these benefits to plateau over time.

6.1.3 Limitation & Evaluation

Increasing Georgia's motor excise tax would provide an immediate influx to GDOT that would help pay to repair and replace many of the state's aging transportation assets. In order to implement a motor fuel tax, agencies would need to appeal to constituent groups who are currently against a fuel tax increase. In their survey of 450 Maryland drivers that used demographic variables to analyze support for different transportation funding mechanisms, Callow and Austin found that men, Democrats, those who drive less, and individuals with more education are more likely to support a fuel tax increase than their counterparts (62). In this survey, respondents preferred an annual 1¢

fuel tax increase versus indexing the fuel tax to inflation (62). This study shows that leaders must work to generate support to facilitate a fuel tax increase.

However, increasing the motor fuels tax – even if it is linked to inflation – has limitations. First, increasing consumer costs will gradually erode the tax's effectiveness if decision makers increased the excise tax without linking it to inflation. This erosion will result in the need for another tax increase, an action that has been difficult to achieve of late due to constituent and political backlash. While linking fuels taxes to inflation is more financially sustainable, Yusuf and O'Connell's paper indicates drivers are only apt to support such a variable tax if it is tied to factors they believe are in need of immediate support, usually road maintenance (59). Even if agencies manage to enact an inflation-based tax, projected increases in fuel economies and the market share of electric vehicles will likely still further reduce the tax's effectiveness, as Chapter 5's results and Nambisan and Vasudevan's research illustrates (36). Another weakness is its inability to capture external costs by not charging users for driving in congested regions or during peak periods (58). Despite these long-term deficiencies, agencies can still use the motor fuels tax to their advantage to gain revenue in the short-term.

If agencies can over-come the aforementioned political and implementation difficulties, increases in the motor fuels tax can provide significant short-term revenue to address immediate infrastructure needs. This is especially true for diesel fuel tax revenue from the freight sector, as the fuel efficiency of single-unit and combination trucks is projected to grow less than personal vehicles (58). The motor fuels tax is also viable because it has a long history of acceptance and familiarity among drivers, facilitating an easier transition (58).

6.2 VMT Fees

Most of the current transportation funding mechanisms in place in the United States do not accurately charge users for their road usage. Inspection and licensing fees do not vary based on how much VMT the vehicle is driven. Motor fuel taxes are indirect user fees, as they charge for consumption to power vehicles, but can vary on a per-mile basis due to fuel economy discrepancies. Historically, fuel taxes were favored due to their ease of implementation, low operations and collection costs, and the lack of technology needed to implement a system that can easily, accurately, and un-intrusively track a vehicle's activity (58). Currently, no agencies in the United States employ a comprehensive VMT fee; however, there have been trials in both Oregon and Iowa, as well as some implementation abroad.

6.2.1 History

The Oregon VMT Pricing Pilot was conducted in 2006 via the Oregon DOT and involved two volunteer gas stations and 285 volunteers (58). Each of the volunteers' vehicles was fitted with a device that tracked VMT and transferred this data at the gas stations (58). The Oregon Pilot resulted in several important findings to help policymakers learn about VMT-fees. The program's leaders found that VMT-pricing is viable, paying these fees at the pump is feasible, potential for evasion is minimal, privacy can be protected, and complex pricing schemes can be implemented (58). Germany, Austria, and Switzerland have all implemented VMT-fees for heavy trucks . Germany's system uses GPS satellites and in-vehicle equipment to charge trucks by the mile, by the axle, and by the vehicle's pollution class (58). The Netherlands also plans to implement a comprehensive VMT-fee system that uses temporal and geographic factors to adjust for congestion (58). Each of these programs utilizes different strategies to implement their VMT-fees from both a technical and administration point of view.

6.2.2 Administration Methods

The methods to collect VMT data vary from a self-reporting honor system to advanced wireless communication. Each of these methods has pros and cons in terms of accuracy, evasion potential, and privacy infringement. Monitoring strategies include self-reporting, odometer checks during vehicle inspection or registration, RFID wireless data transfer, and on-board units (OBU) connected to GPS units that use cellular data transfer (21). Payment systems include payment while fueling, payment during inspection or registration, or RFID or cellular wireless payment. Multiple strategies also exist to enforce these systems including random inspections and checks, default fuel tax payments, and device "heartbeat" signals that alert agencies if drivers tamper with OBUs (21). Finally, plans exist to maintain driver privacy, including third-party organizations, data encryption, and on-board data aggregation. A fully comprehensive evaluation of all of the technical and administrative means in which agencies could implement VMT-fees is outside the scope of this thesis; however, the aforementioned strategies capture the more popular VMT-fee concepts that have been introduced thus far (58). Each of these options has weaknesses that would need to be vetted via thorough and lengthy trial and error testing and widespread education and communication marketing. Because of this, it is unlikely that Georgia or the federal government could design and organize an effective VMT-fee system before 2020.

6.2.3 Projected Rates & Revenue

This thesis assumes a comprehensive VMT-fee structure that charges personal vehicles, single-unit trucks, and combination trucks at different rates. The model charges single-unit trucks and combination trucks differently due to the more adverse environmental and infrastructure affects they induce as compared to personal vehicles. Ideally, the model would also charge light-duty trucks and SUVs more than automobiles, but this thesis' model lacks enough data to project definitively VMT per vehicle class. VMT-fee analysis is provided for the 2009 model, the 2020 projection, and the 2030 projection. Due to data limitations in of the model discussed in Chapters 3 and 4, the pricing structure assumes equal fees throughout the day and region.

6.2.3.1 <u>2009 Revenue Under VMT-Fees</u>

The model first replicated GDOT's 2009 FY revenue. Transferring transportation fees from a fuels tax to a VMT-fee affects different vehicles differently. For example, under Georgia's current fuel tax and $3.00 gasoline, a 50 mpg Toyota Prius pays about 0.4¢/mile in state fuel taxes (63). However, a 20 mpg Ford F-150 pays nearly 1¢/mile due to differences in fuel economy (63). These differences in fuel economy influence geographic and monetary equity. Conversely, an equitable system would charge road users based on how individuals impact the environment and the infrastructure they use. Although GDOT currently charges freight trucks other fees to help absorb their impact on infrastructure, this thesis recommends replacing or supplementing those fees with a truck VMT-fee (46). Table 41 on the following page below illustrates VMT-fee rates that could be implemented that result in a total revenue equal to GDOT's actual 2009 fuel tax revenue.

Table 41: 2009 GDOT Revenue Using Proposed VMT-Fee Rates

Vehicle Type	VMT (billions)	Rate (¢/mi)	Fleet Revenue (millions $)	Total Revenue (millions $)
Personal VMT	96.23	0.6	577.4	961.1
Single Unit Truck VMT	4.09	1.8	73.6	
Combination Truck VMT	8.86	3.5	310.2	

The table shows that using VMT-fee rates of 0.5 ¢/mi, 1.8 ¢/mi, and 3.5 ¢/mi for personal, single-unit, and combination VMT respectively results in approximately the same total fuel tax revenue as actually occurred in 2009. The model assumes the 2009 HPMS VMT values as compared to the model's VMT values in calculating this VMT-based revenue. Under this pricing scheme, personal vehicles contribute roughly 60% of the total revenue versus the approximately 67% seen in the model using the motor fuel tax. Although personal vehicles accounted for 88% of the total VMT, each freight vehicle contributes more to congestion and infrastructure damage due to their greater length and weight. Setting appropriate yet equitable per-mile rates for VMT-fees requires fine adjustments. If freight-truck rates are too high, shipping costs can increase significantly, which could slow economic growth. If temporal and geographic congestion-pricing factors are included in the model, personal vehicles' contributions to revenue might increase due to the number of peak period trips. Revenue from transit vehicles is not included due to the fractional percentage (0.064%) of VMT that transit represented. In addition, a VMT tax break for transit agencies would both incentivize transit usage and aid their operating budgets.

6.2.3.2 2020 and 2030 VMT-Fee Revenue Projection

This projection uses the VMT values from the conservative and aggressive scenarios assuming no motor fuel tax for elasticity purposes. The analysis applies the per-mile rates used in the 2009 VMT-fee analysis in section 6.2.3.1 above to 2020 and 2030 VMT values and compares the revenue generated from each of these scenarios with the projected motor-fuel tax revenue for each scenario. Table 42 illustrates these results.

Table 42: Projected VMT-fee Revenue Using Model Projected VMT Values (in millions of dollars)

Scenario / Revenue	Personal VMT (0.6¢ / mile)	Personal VMT Revenue	Single Unit VMT (1.8¢ / mile)	Single Unit Truck Revenue	Combination VMT (3.5¢ / mile)	Combination Truck Revenue	Total VMT-fee Revenue
2020 Conservative	125.68	$754	4.43	$80	9.59	$336	$1,169
2020 Aggressive	111.12	$667	4.29	$77	9.29	$325	$1,069
2030 Conservative	144.43	$867	5.19	$93	11.25	$394	$1,354
2030 Aggressive	139.16	$835	5.07	$91	10.98	$384	$1,311

The table shows the VMT values per vehicle class and the VMT-fee revenue each fleet would provide as well as each scenario's total revenue. This table uses the same VMT-fee values used in section 6.2.3.1 to approximate actual 2009 fuel tax revenue using a VMT-fee. In a VMT-fee structure, there is no sales tax component, so the higher fuel prices seen in the aggressive scenarios reduce VMT and fuel tax revenue. The table illustrates this phenomenon for both 2020 and 2030, as the conservative scenarios have higher revenue in each year. Because the model projects higher VMT in 2030 versus 2020, the revenue is higher in 2030. The total projected VMT-fee revenues are much lower than the revenues projected by increasing the excise tax and/or linking it to inflation; however, the VMT-fee rates could be adjusted to make up for this discrepancy.

Agencies could achieve this increase by linking VMT-fees to inflation as was done with the excise tax in order to keep up with consumer cost indices. Neither, inflation nor fuel economy improvements would affect a VMT-fee linked to inflation.

6.2.4 Limitations & Evaluation

As the tables above show, VMT-fees offer the potential to significantly increase transportation funding in Georgia, and avoid the revenue erosion caused by inflation, fuel economy improvements, or alternative vehicles. It also offers flexibility in the form of temporal and geographic dynamic pricing that can charge users for other externalities like congestion. However, despite these benefits, agency leaders would face many technical, political, and administrative challenges in implementing a statewide VMT-fee.

6.2.4.1 Administrative Challenges

The task of monitoring VMT, collecting payment, preventing evasion, and maintaining privacy presents a significant technical challenge. Although Oregon had success with its pilot VMT-fee program in 2006, this pilot fitted only 285 vehicles. Expanding a VMT-fee to monitor and receive payments from the projected 10 million+ people and vehicles in Georgia presents numerous challenges such as data management, equipment compatibility, and maintaining the collection system's infrastructure. Initial administration costs are likely to be much higher than fuel tax administration costs, which are approximately 1% of revenue (58). For comparative purposes, the Dutch project their comprehensive VMT program's administration costs to be 5% of total revenue (58). Along the spectrum of strategies that agencies could use to collect revenue, those that are the most simple and least invasive, such as self-reporting and annual checks, are also the easiest to evade. Complex strategies such as on board GPS units that track VMT and send data wirelessly through cellular networks would be more difficult to evade but would present a greater threat to drivers' privacy and might require more maintenance. Each of the payment collection methodologies also has limitations that would make their implementation costly, time-consuming, or both.

6.2.4.2 Privacy Concerns

Privacy would likely be one of drivers' greatest concerns. If agencies chose to implement one of the low-tech metering and payment options, privacy concerns would be minimal, as agencies would only know how many miles each vehicle drove in a given period. However, the more complex payment mechanisms could be intrusive (21). These concerns would be heightened further if temporal and geographic factors were added to VMT-fees. One possible method of easing privacy concerns would be to charge users less for releasing their data to agencies to provide real-time traffic information (21). This trade-off would help users save money while giving transportation agencies valuable travel data. Data aggregation is another method to mitigate privacy concerns. On board units would aggregate VMT by location and time and only transmit the driver's total cost (21). While a statewide VMT initiative would face administrative hurdles, its biggest opposition would likely be from drivers and politicians.

6.2.4.3 Driver Support

Any of the aforementioned VMT-fee programs would be a significant departure from the current motor fuel tax structure for Georgians. Implementing a VMT-fee structure would require careful understanding of public opinion followed by a widespread and persistent marketing and education campaign. This persistence is necessary because several surveys indicate that the current support for VMT-fees is low. Callow and

Austin's data shows that of seven transportation revenue strategies listed including increasing the motor fuel tax, license and registration fees, and toll initiatives, 450 Maryland survey respondents supported a VMT-fee the least (62). Of the respondents, the respondents with the highest income and those who drove the most supported the VMT-fee the least (62).

A separate study by Agrawal and Nixon that synthesized multiple surveys found that VMT-fees did not receive greater than 30% of respondents support unless it was included in the context of improving the environment (28). Agrawal and Nixon also conducted their own national survey of 1,519 individuals across all income and age cohorts. Only 22% of respondents favored a 1¢/mile flat VMT-fee while 36% supported a variable VMT-fee based on vehicles' pollution (28). Their survey also found that younger individuals and transit users were more supportive of either tax (28). These surveys indicate that support for a VMT-fee is currently very low, although survey respondents gave minimal support to nearly every transportation funding measure (62) (28). To successfully implement the VMT-fee, agencies will need to carry out widespread public-involvement plans to understand the root of drivers' aversion to the fees.

In response to the survey evidence of lack of support for VMT-fees, Richard Baker of the Texas Transportation Institute provides steps for how to maximize public acceptance of VMT-fees (63). One of these steps is using the electric vehicle fleet as the test platform for the larger national fleet (63). This plan is advantageous for two reasons. First, electric vehicles constitute a small fraction of the fleet and would be a limited test-bed prior to more widespread implementation. Second, it would ease conventional vehicle drivers' concerns that EV owners would not have to pay a transportation usage fee. Baker also recommends that agencies set the initial per-mile rate to be equivalent to the fuel tax paid by owners of fuel-efficient vehicles (63). While this plan might generate less initial revenue, it would help generate initial support and continue to motivate people to buy fuel-efficient vehicles. Finally, Baker recommends utilizing existing technology and driver habits as much as possible and making any additional technology upgrades optional (63). Agencies could later make incremental adjustments, but he believes that initially maintaining status quo would help to foster support.

6.2.4.4 Evaluation

The short-term and long-term outlooks for the viability of VMT-fees are very different. Implementing a distance based revenue collection mechanism would be a significant departure from the fuel tax in collection, payment, technology, and privacy. Furthermore, the recent economic climate may have caused individuals to be even less receptive to tax increases. The widespread implementation required by a VMT-tax coupled with the necessary preliminary public involvement and small-scale trials necessitates a long-term strategy. During this period, agencies could focus on understanding individuals' aversion to VMT-fees while also publicizing the benefits VMT-fee could provide. The benefits from VMT-fees coupled with congestion pricing include a reduction in peak traffic, mode shifts, travel time reliability improvements, and freight shipping travel time improvements (58). A Brookings Institute report also found that widespread VMT-fees and congestion pricing could reduce annual VMT 11%-19%, which would reduce the U.S. DOT's spending from $89 billion to $51 billion per year. These VMT reductions would have significant indirect benefits, including reductions in emissions with resulting air quality improvements (58). Revenues from VMT-fees would be dependent on the rates set by agencies; however, purchasing power would erode less quickly with VMT-fees versus the motor fuel tax. From an economics and revenue standpoint, VMT-fees provide a sustainable and direct method of charging road users for their road network impact. However, if one considers other factors such as large-scale implementation and public acceptance, distance-based fees face many hurdles. Agencies should take time to educate the public about the benefits of VMT-fees, the changes such a system would bring, and answer any questions about these changes.

6.3 Other Revenue Mechanisms

Many other methods exist to raise transportation funding, ranging from more limited tolling to sales taxes and appropriating funds from a state's general account. Georgia and the Atlanta region have implemented some of these methods, including tolled lanes, high occupancy toll (HOT) lanes with dynamic pricing, and regional sales taxes. This section briefly evaluates each of these methods in terms of its funding sustainability, acceptance, and familiarity amongst Georgians.

6.3.1 Tolled Lanes

Georgia, and specifically the Atlanta region, has limited experience with tolled-lanes, as the State Road and Tollway Authority (SRTA) tolls a small portion of state road GA-400 in northern Atlanta. This project was completed in 1993 and currently generates approximately $59,000 in daily funds (64). SRTA receives these funds and uses them to maintain GA-400, pay debt and interest, and implement other transportation projects along the GA 400 corridor (64). These projects will help relieve congestion and increase mobility in the highly populated northern suburbs of Atlanta.

Like distance-based or VMT-fees, tolled corridors or interstates directly charge roadway users. Although funding from tolls can be an excellent source of local funding to support specific corridors, local, and regional agencies, it likely could not provide enough funding for Georgia to replace the motor fuel tax. As of 2009, there were 277 tolled facilities in the United States, including local roads, bridges, and tunnels, that raised $9.9 billion dollars (58). Although Georgia could likely only implement tolls as a supplement to the motor fuels tax, it could use this funding mechanism in both urban and rural areas, as evidenced by successful toll roads in rural Oklahoma, Kansas, and Pennsylvania (58).

As with VMT-fee systems, public and private entities have made significant advancements in tolling technology and coordination. Very rarely do vehicles need to stop and pay a cashier or place coins in a receptacle; most toll roads, including GA 400, now have overhead scanners that read "tags" or "passes" in vehicles that allow them to register payment while maintaining speeds of 50 mph or greater (64). These advancements allow vehicles to maintain high speeds and operating agencies to collect more revenue via higher car volumes.

One can think of toll lanes as micro-level implementations of VMT-fees that serve particular corridors and regions. These segments can provide significant revenue to maintain and even expand the tolled network; however, the revenue collected from limited roadway segments would likely fail to support an entire state's transportation funding needs (58). Thus, tolled road segments are not a silver bullet but rather a source of supplemental funding to construct a new road or maintain vital links.

6.3.2 High Occupancy Toll Lanes

High Occupancy Toll (HOT) lanes are a specific type of tolled lane. These lanes are often dynamically priced, meaning their price varies based on factors like time of day or congestion. In many instances of HOT lane implementation, an operator chooses not to toll all of the roadway's lanes. This is true for the I-85 dynamically priced HOT lanes in northeast Atlanta that SRTA operates (65). By leaving some lanes un-tolled, drivers have a choice of whether or not to pay for a less congested commute. HOT lanes are often coupled with high occupancy vehicle (HOV) lanes to allow vehicles with 2+ or 3+ passengers to use the toll facility without charge.

Although HOT lanes do raise revenue, their primary objective in the Atlanta region is congestion management and "increase[ing] vehicle throughput along Atlanta's interstate" (65). Because of this, one cannot consider the Atlanta region's current HOT scheme a revenue mechanism but rather a congestion management device. Agencies could increase revenue if they placed HOT lanes on every lane in a roadway, similar to the tolled lanes discussed in section 6.3.1. This would both manage congestion and increase local funding, but would require significant tolls in order to provide the revenue needed at the state level. Thus, HOT lanes are a dual-purpose congestion management and revenue supplement mechanism, but should only be considered a part of the solution to the state's projected transportation funding shortages.

6.3.3 Regional Sales Taxes

In 2006, Georgia was 49th out of 50 states in per-capita transportation spending and experienced significant declines in motor fuel tax revenue due to the recession that began in 2008 (46). In response to this deficit and Georgia's infrastructure needs and perhaps political aversion to increasing Georgia's motor fuel tax rates, the Georgia legislature passed HB 277, the Transportation Investment Act (TIA) of 2010 (66). This legislation created twelve regions in Georgia that can vote independently on a 1¢ transportation sales tax (66). The vote for the sales tax will be held on July 31, 2012, and will pass or not pass on a region-by-region basis.

If the vote does pass, a 1¢ sales tax will be enacted within the borders of that region for ten years, or until the projected funds for that region have been collected (66). The revenue raised from the sales tax will be split into regional and local accounts. In all of the regions except for the Atlanta region, 75% of the revenue will be regional and 25% will be local; in Atlanta, 85% of the funds will be regional and 15% will be local (66). The local funds will be split amongst jurisdictions using a formula that includes population and lane-mile inputs while the regional leaders used public involvement to develop a regional project list.

The Atlanta Regional Roundtable was charged with selecting the final list of regional projects and organizing local project selection. Their economic analysis estimates that the 1¢ sales tax in the Atlanta region would result in $7.22 billion dollars, of which $6.14 billion would be diverted to regional projects and $1.08 billion diverted to the local project account (67). The regional projects vary in size and scale, ranging from small-scale sidewalk and pedestrian improvements to interchange replacements and transit extensions. The current project list has 53% of funds directed to transit projects, which currently receive no funding from Georgia's motor fuel tax (67).

The aforementioned $7.22 billion over ten years would only be used in the Atlanta region, but other regions would have their own referenda to raise their own transportation revenue. These regions would raise less money because of smaller populations and lower sales tax receipts; however, they also have fewer needs. The Atlanta region's average annual receipts over this ten year period are projected to be approximately $722 million, more than 70% of the entire state's 2009 motor fuel tax revenue (46). Per the region's project list, this revenue would be used to rehabilitate and repave roads, improve operations via new signal timings and interchanges, and expand mobility and accessibility via expanded transit and bicycle routes (67).

Every region that sees the TIA pass will immediately receive significant additional flexible transportation revenue. These funds will be used to maintain, expand, and improve the operations of not just Georgia's roadway network but its overall transportation network and will immediately help to solve local, regional, and state transportation backlogs. While even a one-term passage of HB 277 would immediately help to solve regional transportation problems in Georgia, one of the bill's biggest drawbacks is that it only lasts at most ten years. After ten years, each region would revote to pass the 1¢ sales tax for another ten years (66). This uncertainty in the TIA's longevity would make projecting long-term funding difficult and would likely prevent the establishment of long-term operations budgets. From an economic perspective, HB 277 might be undesirable because a sales tax generates its revenue versus a more direct means like tolling or even the motor fuel tax. Nevertheless, in any region it passes, the sales tax would provide much-needed funds to update and expand transportation services.

6.4 Recommendations

Prior to establishing a new revenue framework, GDOT (or any other transportation agency) should first define the objectives they wish to achieve from their funding mechanism. Potential objectives include: increased revenue, more reliable funding, a system that promotes decreased fuel consumption and/or increased transit usage, improved air quality, interoperability with other transportation agencies, and a system that directly charges users for their system usage. In conjunction with creating an objectives list, agencies should also foster extensive public involvement.

Voters will be more likely to pass new transportation revenue mechanisms if agencies work to gain their support. This means educating people about the benefits of a new funding system and listening to and incorporating their concerns in the process. Agencies should present the benefits of new mechanisms by illustrating how revenues could reduce congestion, provide more multi-modal options, and increase safety. As a corollary, agencies should also present the results of no build scenarios. Similar to the increased travel-time figures ARC includes in its 2040 Regional Transportation Plan, these results should include how continued funding deficiencies could result in increased travel times and deteriorating infrastructure. This no-build vs. build comparison would help inform Georgians about the importance of transportation funding and about how a lack of funding could affect their mobility and the state's economy.

Agencies should then use the public involvement findings to refine the aforementioned objectives list. The changes that result from the refinement should be made public in as transparent a manner as possible, making sure to include actual commentary and input to illustrate how public involvement affected the final objectives list. Leaders should also present the monetary and project-related impacts that result from the change in prioritizing objectives. The final revenue strategy would likely contain short-term and long-term transportation funding mechanisms to address both immediate needs and provide sustainable funding. Because of the public involvement aspect of this strategy, there is not enough information available to recommend a "best strategy" for Georgians. Despite this limitation, an eight to ten year plan for how to modify Georgia's transportation finance program is presented below.

Although Georgia does have transportation funding needs and a backlog of projects, multiple factors suggest GDOT should wait for the results of HB 277 before developing a future funding strategy. First, the continued economic uncertainty and high fuel prices will likely make Georgians particularly averse to tax increases. Second, the HB 277 / TIA vote is on July 31. The results of these regional votes will significantly influence transportation revenue in Georgia over the course of the next decade. Prior to presenting or even developing any new short-term funding plans, GDOT should evaluate the result of the July 31 regional votes. If the referendum passes in a majority of the regions, including Atlanta, the TIA may raise enough funds to allow GDOT to concentrate on a long-term funding strategy. Also affecting GDOT's decision will be how many of GDOT's programmed projects were included in each region's project list. If the referendum passes in many regions but there is a significant discrepancy between the lists, GDOT may still need to consider other short-term transportation funding options.

If the final TIA vote on July 31 results in the need for additional short-term funding, the author recommends increasing the excise fuel tax by either 5¢ or 10¢. Despite the fact that politicians have avoided motor fuel tax increases in recent history, this action would be the easiest and quickest method of raising additional revenue in the short-term because the necessary infrastructure and standard operating procedures are already in place. Section 6.1's results illustrate the short-term revenue increases that could be achieved from increasing the sales tax and/or indexing it to inflation. The majority of these revenue increases occur between the present and 2020, as the results show that fuel economy improvements and electric vehicle market penetration erode the revenue increases between 2020 and 2030. In conjunction with an attempt to raise the motor fuels tax, the author also recommends that GDOT and the Atlanta region's leaders push forward to implement the planned I-75 managed lanes and consider managed lanes and/or tolled lanes throughout the region's interstate network.

While engaged in these efforts, GDOT should work to develop a framework for a statewide distance-based tax (VMT-fee). This program should have the short-term goal of conducting a large-scale trial in late 2015, three years after the initial HB 277 vote in 2012. The author recommends using electric and plug-in hybrid electric vehicles for the trial, based on Richard Baker's research to increase public acceptance (63). This three-year delay between 2012 and 2015 would give GDOT the time to research previous VMT-fee efforts and work with vendors to develop a robust and interoperable system. It would also place significant time between the HB 277 vote and the trial, which would help to minimize citizens' complaints that the state was attempting to implement stacked transportation taxes. Waiting until 2020 to phase out any motor fuel taxes also aligns with the benefits of increasing the excise tax, as the tables in section 6.1 indicate these benefits decline between 2020 and 2030 due to fuel economy improvements and increased EV market share.

In creating a VMT-fee, Georgia should work with other states and the federal government to implement an interoperable system to ensure that technologies and policies are flexible and compatible with other potential VMT-fee programs at the state or federal level. The state should also conduct extensive public involvement and attempt to integrate the needs of its citizens with the requirements of creating a robust and interoperable system. Marketing campaigns should also be used to educate drivers about potential metering and payment systems and to mitigate privacy concerns before they arise. States should also research how to minimize administration costs for a VMT-fee mechanism, as the Netherlands spends 5% of its VMT-fee revenue operating the system (58). Costs of this magnitude might weaken support for the system, as citizens would be concerned about system inefficiencies.

Once system developers gather the necessary public and private input, the author recommends carefully implementing the system in 2020. The initial scheme should use a flat fee with rates that vary by vehicle class (automobile, freight trucks) for an initial period to allow drivers to transition to the new system. After drivers have time to adjust, the author recommends slowly transitioning from a flat fee system to one that charges for external costs, such as congestion and time of day. Continuous public involvement should occur throughout the development and after the implementation of the VMT-fee with as much transparency as possible in order to gain drivers' trust.

The above plan represents a high-level policy recommendation that depends greatly on the results of the July 31, 2012, Transportation Investment Act referenda votes. Other short-term funding mechanisms could be implemented on a more local or regional basis in addition to, or in place of those mentioned in this plan. The author acknowledges it is important to recognize that Georgia's complex future demographic and political environments will make implementing any new transportation funding difficult. GDOT and other agencies should emphasize that no single mechanism can completely solve its funding concerns. Leaders should consider all of the plans and ideas presented in this chapter, as well as other innovative and effective ideas that develop. Georgia's policy and transportation decision makers should also engage in persistent and open public involvement to hear citizens' concerns, and incorporate these concerns in developing plans. Finally, leaders should recommend decisions that most benefit the state's citizens and economy over the long-term, even if these decisions are unpopular in the short-run.

CHAPTER 7 CONCLUSIONS

Transportation infrastructure is vital to the movement of people and goods and the world's economy. The assets that comprise this infrastructure require large capital investments, have long service lives, and can shape the development of entire cities and regions. In Georgia, the motor fuel tax is the primary mechanism that provides capital to fund these long-term investments. The literature discussed in Chapter 2, and the model described in Chapters 3 and 4 illustrate that numerous factors including VMT, fuel economy, vehicle technology, fuel prices, population density, freight activity, and the economic climate affect fuel tax revenue. This thesis' model prompts users for inputs and them along with recent data from the 2009 NHTS and 2009 HPMS to output projected motor fuel tax revenue in Georgia in 2020 and 2030.

Although the model created in this research has limitations, including being unable to predict radical innovations or understanding the response to extreme increases in fuel prices, it attempts to counteract these deficiencies with its flexibility and ease of use. Users can quickly assess the how different changes in technology, demographics, and the environment affect fuel tax revenue. As time passes, users can update the model's databases with new information to maintain its relevance. The author acknowledges that uncertainty is unavoidable when predicting something as volatile and complex as fuel tax revenue two decades into the future. However, the model attempts to combat this uncertainty by allowing the user to ascertain a range of outputs via the aforementioned inputs. Chapter 5 illustrates this range by discussing "conservative" and "aggressive" scenarios for both 2020 and 2030.

The results from these scenarios indicate that fuel tax revenue growth will slow on an absolute basis and decline on a per-mile and per-capita basis through 2020. Between 2020 and 2030, the model predicts absolute, per-capita, and per-mile revenue declines between 2020 and 2030. In 2020, the model predicts that the aggressive scenario will produce greater revenue than the conservative scenario, due to higher fuel prices driving higher revenue from the sales tax. In 2030, the model predicts the conservative scenario to produce greater revenue due to the aggressive scenario's greater fuel economy improvements and electric vehicle market penetration. However, the model predicts that the revenue in both of the 2030 scenarios will be approximately only 120 million dollars greater than the actual revenue seen in 2009. This decline in revenue is projected on top of the fact that GDOT spent much of its 2009 budget paying off debts from previous years and (46). If Georgia fails to generate the revenue needed to maintain its transportation infrastructure, its citizens will face decreasing mobility, accessibility, movement of goods, and even safety.

Chapter 6 discusses and evaluates many different strategies to increase transportation funding in Georgia. It also illustrates how implementing these mechanisms can affect the revenue under each of these conditions. However, developing a funding plan that is sustainable over the long-term, provides short-term funding for immediate projects, and gains public acceptance will require a mix of strategies. The complexity and current lack of public acceptance associated with some of the longer-term funding strategies means that agencies in Georgia will need to use multiple strategies to gain transportation revenues.

The author's recommendation for Georgia's transportation revenue includes GDOT establishing objectives for its funding mechanisms and presenting these concepts to the public. Chapter 6 discusses how the public is currently averse to any increase in transportation tax rates or funding, especially if the revenue is derived from new mechanisms. Public involvement will help agencies understand citizens' concerns and educate drivers about how changes to the tax structure could actually benefit them.

Specifically, the author recommends that GDOT evaluate the results of the July 31, 2012, Transportation Investment Act votes prior to developing or implementing any new short-term funding strategies. If enough regions pass the referendum and include the right list of projects, the projected revenue received from the sales tax may reduce GDOT's short-term funding concerns. If the vote does not pass, GDOT should push to increase its motor fuel excise tax to provide immediate funding benefits, as shown in Chapter 6. The analysis shown in Chapter 6 indicates that fuel economy improvements and alternative vehicles erode the benefits provided by excise tax increases after 2020. Because of this erosion, the author recommends that GDOT and Georgia's transportation leaders design and calibrate a VMT-fee system to implement by 2020. During this period, leaders should reference previous VMT-fee trials and studies and conduct extensive public involvement to understand citizens' concerns. The combination of the TIA or an increase to Georgia's excise tax ameliorate and a future VMT-fee would help to solve GDOT's short-term funding concerns as well as implement a revenue structure that would provide long-term, sustainable transportation funding.

If steps are not taken to reverse recent declining revenue trends, increasing population, VMT, and congestion coupled with slow growth or flat lining in fuel tax revenue will significantly affect GDOT's ability to maintain, operate, and expand its assets. This inability would result in decreased mobility, increased travel times, and difficulty in maintaining vital assets like bridges and interchanges. Were this to occur, Georgia's economic competitiveness would likely suffer, as firms would look to other cities like Charlotte and Dallas that are investing more in their transportation assets.

GDOT's maintenance and operations activities are limited to the funds they receive, and GDOT is further hamstrung by the fact that some of this revenue goes to pay debt obligations. The results from Chapter 6 indicate that increasing Georgia's current fuel excise tax or implementing other revenue mechanisms can increase this revenue. Policy and decision makers in Georgia's legislature must informed of the current fuel tax's long-term inability to fund the state's critical infrastructure projects and the aforementioned effectiveness of other revenue mechanisms. Leaders and citizens alike should take a long-term outlook in developing and implementing transportation measures that not only maintain their mobility, accessibility, and safety, but also ensure this same quality of life for future generations.

REFERENCES

1. **Clarke, Wes, Brown, Warren and Hauer, Matt.** *The Motor Use Fuel Tax in Georgia: Collection Efficiency, Trends, and Projections.* Carl Vinson Institute of Government, The University of Georgia. Athens : The University of Georgia, 2010.

2. **NHTSA.** Cafe Fuel Economy. *National Highway Traffic Safety Administration.* [Online] October 2011. [Cited: October 12, 2011.] http://www.nhtsa.gov/fuel-economy.

3. **Gilbert, Richard and Perl, Anthony.** *Transportation Revolutions: Moving People and Freight Without Oil.* Canada : New Society Publishers, 2010.

4. **Atlanta Regional Commission.** *2030 Regional Transportation Plan.* Atlanta : s.n., 2007.

5. —. *Atlanta Region Plan 2040 Draft.* Atlanta : Atlanta Regional Commission, 2011.

6. **Mid-Ohio Regional Planning Commission.** *CapitalWays Transportation Plan: Regional Transportation Plan, 2008 - 2030.* Columbus, Ohio : MORPC, 2008.

7. **Chicago Metropolitan Agency for Planning.** *Updated 2030 Regional Transportation Plan for Northeastern Illinois.* Chicago : s.n., 2008.

8. **Metropolitan Council.** *Regional 2030 Transportation Policy Plan.* Minneapolis, Minnesota : s.n., 2010.

9. **Metro Metropolitan Planning Organization.** *2035 Regional Transportation Plan.* Portland, Oregon : s.n., 2010.

10. **Cambridge Systematics.** *2005-2035 Georgia Statewide Transportation Plan.* Atlanta : Georgia Department of Transportation (GDOT), 2006.

11. **Caltrans.** *California Transportation Plan 2025.* Sacramento, California : s.n., 2006.

12. **Texas Department of Transportation.** *Statewide Long-Range Transportation Plan 2035.* Austin, Texas : s.n., 2010.

13. **Regional Economic Models Inc.** 2009-2040 Projections. *Atlanta Regional Demographic & Economic Projection Data.* Atlanta : Atlanta Regional Commission, 2010.

14. **ICF International.** *Long Range Strategic Issues Facing the Transportation Industry.* Washington DC : NCHRP, 2008.

15. **AASHTO.** *NCHRP 20-83A: Long-Range Strategic Issues Facing the Transportation Industry.* Washington D.C. : Keck Center of The National Academies, 2010. Workshop.

16. **Transportation Research Board.** *Commuting in America III: The Third National Report on Commuting Patterns and Trends.* Washington D.C. : s.n., 2006.

17. **Environmental Protection Agency and National Highway Traffic Safety Administration.** *2017-2025 Model Year Light-Duty Vehicle GHG Emissions and CAFE Standards: Supplemental Report.* Washington D.C. : s.n., 2011.

18. **Center for Automotive Research.** *Deployment Rollout Estimate of Electric Vehicles 2011-2015.* Ann Arbor : s.n., 2011.

19. **Federal Highway Administration.** Major Flows by Truck To, From, and Within Georgia: 2007 and 2040. *Freight Management Operations.* [Online] U.S. Department of Transportation, February 27, 2012. [Cited: March 16, 2012.] http://www.ops.fhwa.dot.gov/freight/freight_analysis/state_info/georgia/truckflow.htm.

20. **Energy Information Administration.** *Annual Energy Outlook 2011 with Projections to 2035.* Washington D.C. : U.S. Department of Energy, 2011.

21. **Sorensen, Paul, RAND Corporation.** *NCHRP 161: System Trials to Demonstrate Mileage-Based Road Use Charges.* ICF International. s.l. : Transportation Research Board, 2010.

22. *Tracking National Household Vehicle Usage by Type, Age, and Area in Support of Market Assessments for Plug-In Hybrid Electric Vehicles.* **Zhou, Yan, Vyas, Anant D. and Santini, Danilo.** Washington D.C. : Transportation Research Board Conference, 2012. 12-4348.

23. **Oak Ridge National Laboratories.** *Interim 2009 Comparison Report: Revised Draft.* Albany : New York Department of Transportation, 2011.

24. **Agbelie, Bismarck B.R., et al.** *Forecasting of Highway Revenues Under Various Options.* Joint Transportation Research Program, Purdue University & Indiana Department of Transportation. West Lafayette, IN : JTRP/FHWA/Purdue University, 2010.

25. **Litman, Todd.** *The Future Isn't What It Used to Be: Changing Trends and Their Implications for Transport Planning.* Victoria : Victoria Policy Institute, 2011.

26. **Small, Kenneth A and Van Dender, Kurt.** If Cars Were More Efficient, Would We Use Less Fuel? *Access: Transportation Research at the University of California.* Fall 2007, pp. 8-13.

27. *Findings from the 3rd Annual Symposium on Mileage-Based User Fees.* **Wood, Nicholas, Goodin, Ginger and Baker, Richard.** Washington D.C. : 2012 Transportation Research Board Conference, 2012.

28. *What Do Americans Think About Federal Transportation Tax Options? Results From Year 2 of a National Survey.* **Agrawal, Asha Weinstein and Nixon, Hilary.** Washington D.C. : 2012 Transportation Research Board Conference, 2011.

29. **Steiner, Christopher.** *$20 Per Gallon: How the Inevitable Rise in the Price of Gasoline Will Change Our Lives for the Better.* New York : Grand Central Publishing, 2009.

30. **Kotkin, Joel.** *The Next Hundred Million: America in 2050.* New York : Penguin Press, 2010.

31. **Federal Highway Administration.** 2009 National Household Travel Survey Database. Washington DC : U.S. Department of Transportation, June 2011.

32. —. *2009 National Household Travel Survey User's Guide Version 1.* Washington D.C. : U.S. Department of Transportation, 2011.

33. **Santos, A., et al.** *Summary of Travel Trends: 2009 National Household Travel Survey.* Washington D.C. : U.S. Department of Transportation, 2011.

34. **U.S. Census Bureau.** 2009 Data Release. *2009 American Community Survey.* Washington D.C. : United States Census Bureau, 2011.

35. **Federal Highway Administration.** Highway Performance Monitoring System Data. Washington D.C. : U.S. Department of Transportation, 2010.

36. **Vasudevan, Vinod and Nambisan, Shashi S.** *Impacts of Energy Regulations and Vehicular Technologies on Fuel Tax Revenues.* Indian Institute of Technology. Kampur : s.n., 2011.

37. **Pickrell, Don, et al.** State VMT Forecasting Model. *3rd Expert Panel Meeting.* Boston : John A. Volpe Center, 2010.

38. *Automobile Ownership and Travel of the Poor: Evidence from the 2009 National Household Travel Survey*. **Blumenberg, Evelyn and Pierce, Gregory.** Los Angeles : 2012 Transportation Research Board Conference, 2011.

39. **McMullen, B. Starr and Zhang, Lei.** *Techniques for Assessing the Socio-Economic Effects of Vehicle Mileage Fees.* Portland, Oregon : Oregon Transportation Research and Education Consortium, 2008.

40. **Coupal, Dustin and Toews, Jason.** Historical Charts. *Gas Buddy.* [Online] 2011. [Cited: February 20, 2012.] http://www.gasbuddy.com/gb_retail_price_chart.aspx?time=3.

41. **National Research Council.** *Technologies and Approaches to Reducing the Fuel consumption of Medium- and Heavy-Duty Vehicles.* Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles. Washington D.C. : National Academies Press, 2010. p. 18.

42. **Federal Highway Administration.** Highway Statistics 2009: Annual Distance Traveled in Miles and Related Data. *Policy Information.* [Online] U.S. Department of Transportation, January 3, 2012. [Cited: March 12, 2012.] http://www.fhwa.dot.gov/policyinformation/statistics/2009/vm1.cfm.

43. **United States Energy & Information Administration .** Gasoline & Fuel Update. *Petroluem & Other Liquids.* [Online] March 12, 2012. [Cited: March 12, 2012.] http://www.eia.gov/petroleum/gasdiesel/.

44. **U.S. Census Bureau.** Truck Fuel Types. *Vehicle Technologies Program.* [Online] Vehicle In Use Survey, November 15, 2005. [Cited: March 15, 2012.] http://www1.eere.energy.gov/vehiclesandfuels/facts/2005/fcvt_fotw368.html.

45. **Federal Transit Administration.** 2009 National Transit Database. Washington D.C. : s.n., 2010.

46. **Georgia DOT.** *Investing In Our Future.* Atlanta : GDOT, 2009.

47. **Southworth, Frank and Gillett, Jessica.** *Trucking in Georgia: Freight Performance Measures.* Atlanta : Georgia Transportation Research Center, 2011.

48. **Task, Aaron.** As America's Middle Class Shrinks, P&G Adopts "Hourglass" Strategy. *Yahoo! Finance.* [Online] Yahoo!, September 11, 2011. [Cited: March 4, 2012.] http://finance.yahoo.com/blogs/daily-ticker/america-middle-class-shrinks-p-g-adopts-hourglass-145429009.html.

49. **Deffeyes, Kenneth S.** *Hubbert's Peak: The Impending World Oil Shortage.* Princeton : Princeton University Press, 2008.

50. *Understanding Spatiotemporal Patterns of Hybrid Electric Vehicle Adoption in the United States.* **Keith, David, Sterman, John and Struben, Jeroen.** Washington D.C. : 2012 Transportation Research Board Conference, 2012.

51. *US Household Preferences for Alternative-Fuel Vehicles: Results from a National Survey.* **Saphores, Jean-Daniel and Nixon, Hilary.** Washington D.C. : 2012 TRB Conference, 2012.

52. **U.S. Department of Energy.** Heavy Truck Miles by Age. *Vehicle Technologies Program.* [Online] March 14, 2005. [Cited: November 10, 2011.] http://www1.eere.energy.gov/vehiclesandfuels/facts/2005/fcvt_fotw363.html.

53. **Bureau of Transportation Statistics.** Table 3-10: National Transportation and Economic Trends. *RITA: Research and Innovative Technology Administration.* [Online] August 4, 2011. [Cited: November 10, 2011.]

http://www.bts.gov/publications/national_transportation_statistics/html/table_03_10.html
.

54. **Litman, Todd.** *Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior.* Victoria : Victoria Transport Policy Institute, 2011.

55. **Bureau of Transportation Statistics.** Table 1-17: New and Used Passenger Car Sales and Leases. *RITA: Research & Technology Innovation Administration.* [Online] U.S. DOT, March 15, 2011. [Cited: March 15, 2012.] http://www.bts.gov/publications/national_transportation_statistics/html/table_01_17.html
.

56. **Energy Information Administration.** Main References Case Tables (2008-2035). *Annual Energy Outlook 2011.* [Online] January 23, 2012. [Cited: March 13, 2012.] http://www.eia.gov/forecasts/aeo/tables_ref.cfm.

57. **U.S. Census Bureau.** National Population Projections Released 2008 (based on 2000 Census). *U.S. Population Projections.* [Online] 2008. [Cited: March 13, 2012.] http://www.census.gov/population/www/projections/summarytables.html.

58. **National Surface Transportation Infrastructure Financing Committee.** *Paying Our Way: A New Framework for Transportation Finance.* 2009.

59. *Indexing the Gas Tax to Indicators of Need: An Analysis Revenue Adequacy with Indexing the Gas Tax to Indicators of Need: An Analysis Revenue Adequacy with Indexing the Gas Tax to Indicators of Need: An Analysis Revenue Adequacy with Indexing the Gas Tax* . **Yusuf, Juita-Elena and O'Connell, Lenahan.** Washington D.C. : 2012 Annual Transportation Research Board Conference, 2011.

60. **Eger III, Robert and Smith, William J.** *Fiscal Research Center.* Atlanta : Andrew Young School of Policy Studies, Georgia State University, 2006.

61. **U.S. Bureau of Labor Statistics.** Current Inflation Rates 2002-2012. *US Inflation Calculator.* [Online] 2012. [Cited: March 16, 2012.] http://www.usinflationcalculator.com/inflation/current-inflation-rates/.

62. **Callow, Michael and Austin, Nathan K.** *The Mediating Role of Motorists' Evaluation of Current Roadway Conditions in Determining Their Willingness to Pay for Future Improvements.* s.l. : Morgan State University National Transportation Center, 2011.

63. *Implementing Vehicle Mileage Fees to Maximize Public Acceptability* . **Baker, Richard T.** Washington D.C. : 2012 Annual Transportation Research Board Conference, 2011.

64. **Georgia State Road & Tollway Authority.** GA 400. *Programs & Studies.* [Online] 2012. [Cited: March 20, 2012.] http://www.georgiatolls.com/programs/ga-400/.

65. **Evans, Gena.** State Road and Toll Authority Lecture. [Lecture]. Atlanta, Gerogia : Georgia Institute of Technology Civil & Environmental Engineering, February 23, 2012.

66. **Georgia Department of Transportation.** HB 277 Transportation Investment Act of 2010. [Online] May 19, 2010. [Cited: March 20, 2012.] http://www.it3.ga.gov/Documents/GDOT%20Board%20May%2019%202010.pdf.

67. **Atlanta Regional Roundtable.** Following The Money. *Regional Transportation Referendum.* [Online] September 12, 2011. [Cited: March 20, 2012.] http://www.atlantaregionalroundtable.com/documents/following_the_money_v2.pdf.

68. **CalculatedRisk.** Calculated Risk: Finance and Economics. *DOT: Vehicle Miles Traveled Decline 0.9% in November.* [Online] January 23, 2012. [Cited: January 24, 2012.] http://www.calculatedriskblog.com/2012/01/dot-vehicle-miles-driven-declined-09-in.html.

69. **Hughes, Jonathan E., Knittel, Christopher R. and Sperling, Daniel.** *Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand.* Cambridge : National Bureau of Economic Research, 2006.