GEORGIA DOT RESEARCH PROJECT 10-14

FINAL REPORT

Assessment of the Impact of Future External Factors on Road Revenues

Georgia Department of Transportation

OFFICE OF RESEARCH

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GDOT Research Project No. 10-14

Final Report

ASSESSMENT OF THE IMPACT OF
FUTURE EXTERNAL FACTORS ON ROAD REVENUES

By

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16. Abstract:

This report examines the factors that affect future motor fuel tax revenue in Georgia. These factors influence vehicle miles traveled (VMT) and fuel economy, and can be demographic, environmental, technological or political. Numerous sources including MPO and statewide transportation plans, academic and government reports, and futurist projections were surveyed to ascertain these factors. Afterward, the qualitative knowledge gained from this literature review was combined with databases such as the 2009 National Household Travel Survey and U.S. Census data to create an input-output model that projects Georgia's motor fuel tax revenue in 2020 and 2030. Prior to projecting future revenue, the model compares estimated 2009 Georgia VMT and revenue values with established, actual VMT and revenue values to ensure the soundness of the model's logic. In both the 2009 and projection models, the model segments Georgia's fleet into three categories: personal, freight, and transit to more precisely specify vehicle fuel economies and calculate overall fleet fuel consumption. The model prompts the user for many inputs, allowing users to evaluate how multiple input scenarios can affect fuel tax revenue. The model's output indicates that fuel economy increases, projected fuel costs, and the market penetration of electric vehicles could stifle absolute motor fuel tax receipts and drastically reduce per-capita fuel tax revenue.

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EXECUTIVE SUMMARY

The objectives of this research were to: 1) identify those factors that affect state highway revenues in Georgia, 2) develop a conceptual framework of the key factors that influence highway revenues, and 3) develop a model that can be used to assess the implications on revenues of changes in a variety of factors that have been shown to influence overall revenue levels. The model is intended to be a "revenue estimation toolbox" that allows GDOT planners and budget officials to use an easy-to-use input-output process to assess quickly how different scenarios could impact future fuel tax revenue in Georgia. A literature review of both academic journals and government agency reports was used to identify key variables that have been identified as influencing vehicle miles traveled, fuel consumption and hence gas tax-generate revenues.

Much of the data for the model came from the 2009 National Household Travel Survey (NHTS), which included over 7,000 household and 15,000 vehicle records from Georgia. Other data used throughout the modeling process was obtained from the U.S. Census Bureau and the FHWA. Census data were used to extrapolate average values obtained from the 2009 NHTS database to the state level as well as in model calibration. The FHWA data were used in calculating, calibrating, and projecting freight VMT, as well as observing historical VMT trends. The National Transit Database (NTD) was used in tabulating transit VMT. The model was validated by estimating 2009 motor fuels tax revenue. In the model, the fleet was split into personal, freight and transit categories, with the freight category further split into single unit and combination trucks. This categorization was made in order to provide greater revenue source transparency within the model and more model inputs to the various model users. In addition, the data sources for each of these categories were quite different, and each fleet had significantly different VMT values and fuel economies. After splitting the fleet into categories, the VMT and fuel economy for each fleet category were estimated. Figure ES-1 shows the makeup of the analysis framework.

The model's estimated 2009 revenue was accurate to within less than 3% of the published revenue, which implies that the logic used in creating the model is acceptable for future revenue projections. Personal VMT accounts for nearly two-thirds of the total revenue and the revenue from freight VMT accounts for nearly one-third of total revenue. Revenue from transit services was less than 1% of the total revenue.

The model was used to predict transportation revenue implications for four scenarios – a higher revenue scenario with more conservative inputs and a lower revenue scenario with more extreme increases in fuel economy and electric vehicles – each for 2020 and 2030. For the "high revenue" scenario, there is a relatively low decrease in 2020 per capita motor fuels tax revenue as compared to 2009 values. This scenario assumed a vehicle fleet mix of 40% SUVs and 60% cars, 2.70 persons/household, and 2009's income distribution. This scenario showed a range of 1 to 3% reduction in per capita revenue from transportation sources in the state. For 2030, this became a 19% reduction in per capita revenue from transportation sources. The lower revenue scenario, with more aggressive fuel economy and electric vehicle projections, showed much higher per capita revenue reductions, a

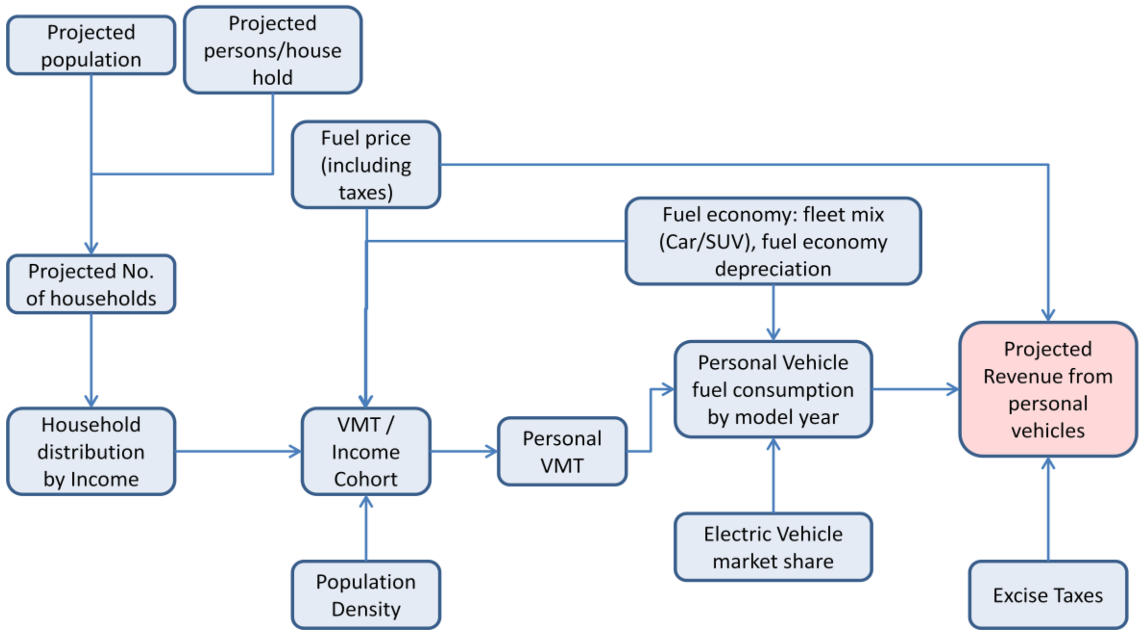

Figure ES-1: Analysis Framework for Estimating Future Transportation Revenues

range of 1 to 5% reduction in 2020 and a 25% reduction in 2030. The 2030 projections predict not only lower per-capita revenues, but also lower absolute revenues (in 2009 dollars). Thus, while revenues are expected to be relatively stable through 2020, given the above inputs, a decline in revenue is projected to occur during the 2020s

Although there are numerous inputs to the model, it was found that some inputs have a greater impact than others – especially in the 2030 projections. Some of the most important variables in the model are those that impact how many persons and households will be in Georgia in 2020 and 2030. Changing the number of people who are projected to live in the state or how densely they live alters the number of households generating travel. Although credible sources from the Atlanta Regional Commission were used in projecting these variables, it is difficult to know how demographics will change over a 10 – 20 year period.

Fuel economy improvement also has a significant impact on future revenue. The model allows users to input transit and freight fuel economy improvements in the form of a percentage increase over 2009. Even a small difference in percentage can make a significant difference in predicted revenue – especially in 2030. In conjunction with fuel economy, projected electric vehicle market share also has a very significant impact on revenue, again with a greater impact seen in 2030. As electric vehicle market penetration increases above 20%, a large number of miles are not being fueled by fuel and thus do not contribute to fuels tax revenue.

The ratio of freight VMT to GDP growth is also a significant variable, as even small growth in freight VMT can result in relatively large increases in motor fuels tax revenue. The model recommends a range of between 0.08 and 0.12 for this input, and thus there is only a small range of potential values to input; however, increasing the ratio from 0.09 to 0.11 can affect revenue substantially. As was explained earlier in the document, this input relates shipping activity to economic growth. In this model, economic growth is fixed as predicted by the REMI model.

Finally, the excise tax rate and sales tax percentage are the most significant variables and are the variables that GDOT likely has the most influence over. Increasing the excise or sales tax rates can recover the revenue lost to increased fuel economy or electric vehicles. Each of the scenarios shown in the previous section assumed constant excise and sales tax rates.

From GDOT's perspective, perhaps the most important conclusion that can be drawn from using the Revenue Toolbox is that significant declines in motor fuels tax revenue are possible within the next 10 to 20 years. While some of the inputs used were more aggressive than others, more aggressive scenarios should at least be considered and visualized.

Chapter 1: Introduction

1.1 Background / Motivation

Motor fuel taxes are currently the major funding source for transportation agencies at both the federal and state levels. These taxes are either 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 and allocated toward Georgia's general fund. Figure 1 illustrates the motor fuel tax collection process that contributes to GDOT funding.

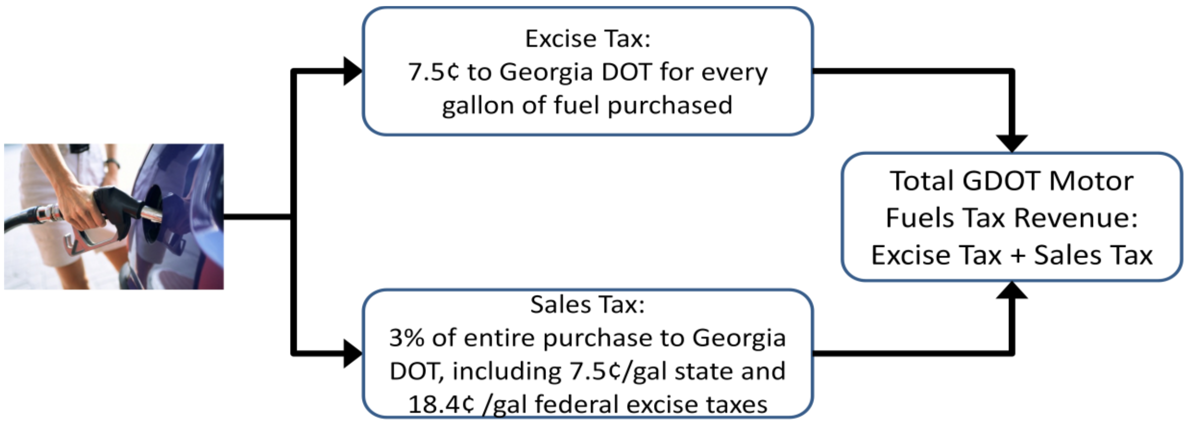

Figure 1: Georgia Motor Fuels Tax Collection

From a transportation agency's perspective, it is important to understand which factors affect motor fuels tax revenue in order to budget and program future transportation projects. The importance of making dollars stretch further is especially important today as many major transportation assets are approaching or have exceeded their design lives, and thus the demand for limited revenues is great. Figure 2, for example, illustrates how vehicle miles traveled (VMT), vehicle fuel economy, and the prevailing fuel price can impact the level of fuel tax revenue.

The price of gasoline impacts total revenue in two ways: the amount of revenue generated from the tax itself and the impact that fuel price has on overall demand via elasticity. Thus, rising fuel prices increase tax revenue for the agency on a per-gallon basis, but on average decreases the number of gallons purchased due to the elasticity of demand with respect to price; consumers often 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 that increasing vehicle fuel economy leads to decreasing revenue because a vehicle can travel the same distance on less fuel (assuming the gas tax is not increased to offset the declining revenues).

Figure 3 shows historical VMT trends from 1971 to mid 2011.

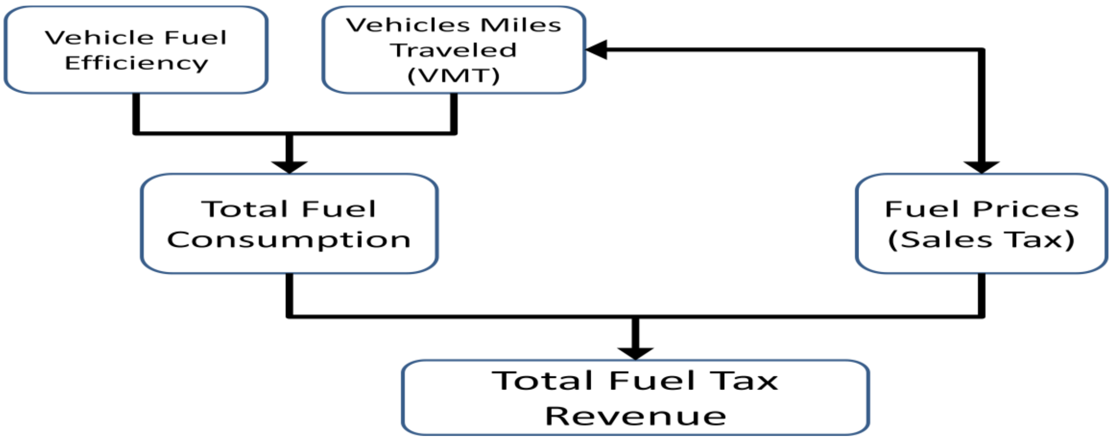

Figure 2: Factors Affecting Fuel Tax Revenue

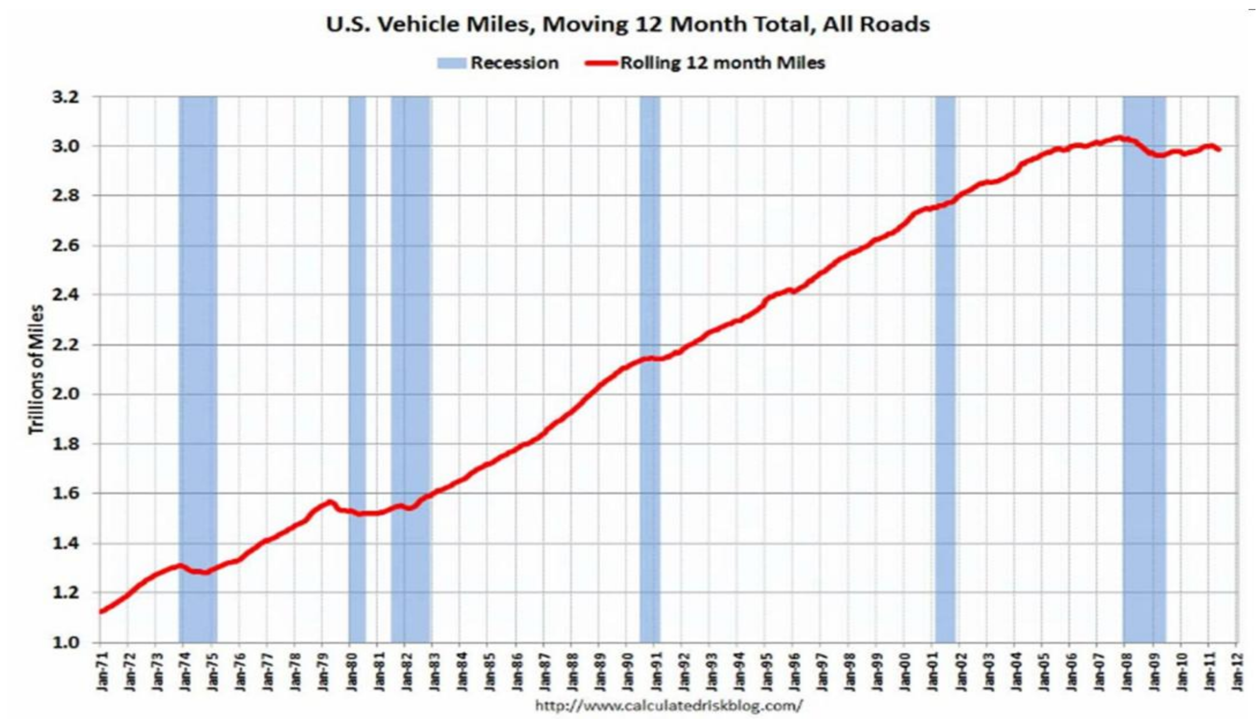

Figure 3: United States VMT History

As shown, aggregate VMT rose steadily from 1971 to 2008; however, it is clear that this increase was not steady or monotonic. First, total aggregate VMT stagnated or decreased during every recession that occurred between 1971 and 2011. As most state departments of transportation experienced, aggregate VMT began to flatten out in 2005 in advance of the most recent economic recession.

Fuel economy is the second component that influences the amount of fuel consumed at both the individual and aggregate levels. Until the mandated increase in economy standards that took effect in 2010, fuel economy was unaffected by manufacturers and driver behavior alike, as the Corporate Average Fuel Economy (CAFE) standards for passenger cars remained 27.5 mpg from 1992 to 2010; the standards for light duty vehicles remained constant at 20.7 mpg from 1996 to 2004. However, manufacturers, consumers, and the federal government have all responded in their own way to higher fuel prices in recent years. Consumers have purchased more fuel efficient hybrid vehicles at increasing rates as well as more fuel efficient conventional vehicles. Manufacturers are now selling a wider range of more fuel efficient and hybrid vehicles, which include not only passenger vehicles but also sport-utility vehicles (SUVs), and luxury vehicles. The past year has seen the release of vehicles with alternative technologies such as the Chevrolet Volt, a plug-in hybrid electric vehicle, and the Nissan Leaf, a pure electric vehicle. In addition to electric vehicles, research is also still ongoing to develop other vehicle technologies such as fuel cell vehicles (FCV) powered by hydrogen. The federal government has increased the CAFE standards, with a 35.5 mpg standard set for 2016 and a 54.5 mpg standard still being considered for 2025. Such an increase would dramatically improve the fuel economy of the nation's and Georgia's vehicles, while also providing environmental and energy security benefits.

Slowing growth in VMT and rapidly increasing vehicle fuel economy could have significant impacts on fuel consumption and thus fuel tax revenue. As more alternative fueled vehicles enter the nation's fleet, and assuming no alternative means of taxing the use of such vehicles exists, motor vehicle-based revenue will continue to decline. Understanding the long-term trends of factors such as VMT and fuel economy, not only the magnitude but also the timing of their impact on motor fuels tax revenue, is important for agencies responsible for a state's highway network.

1.2 Research Objective

The objectives of this research were to: 1) identify those factors that affect state highway revenues in Georgia, 2) develop a conceptual framework of the key factors that influence highway revenues, and 3) develop a model that can be used to assess the implications on revenues of changes in a variety of factors that have been shown to influence overall revenue levels. This report complements the model, which is provided in a separate spreadsheet, by describing the research background, model development thought process, model instructions, and the results from different scenarios. The model is intended to be a "revenue estimation toolbox" that allows GDOT planners and budget officials to use an easy-to-use input-output process to assess quickly how different scenarios could impact future fuel tax revenue in Georgia. It should be noted that the model does not project future expenditures and thus additional information is needed to address potential shortfalls. However, it can be used to assess funding gaps when compared to expected needs and to help planners and decision makers understand how fluctuations in different inputs would likely affect overall revenue.

1.3 Report Organization

This report is organized in the following manner. Chapter 2 summarizes the literature and technical reports that were reviewed for this research, with those references that provided particular help in developing the model highlighted. The process for developing a model that estimates 2009 motor fuel tax revenue in Georgia is described in Chapter 3. The chapter also compares the modeled 2009 VMT and motor fuel tax revenue to actual VMT and fuel tax revenue in that year to validate the model. Chapter 4 describes the variables used to project future revenue, discusses why each projection year was chosen and presents screenshots from the model file to introduce the model user to the model format. Chapter 5 provides instructions on how to use the model as well as references where model users should look within the model for further assistance. Chapter 6 presents the results of future scenario analyses where selected model inputs are changed to reflect possible future changes in vehicle fuels and technology. It should be noted that the input values used in these scenarios should not be considered default values; they were simply used for illustrative purposes. Chapter 7 concludes the report by discussing which variables have the most impact on future fuel tax revenue in Georgia.

Chapter 2: Literature Review

A thorough literature review was undertaken prior to constructing the model. Sources included metropolitan planning organization (MPO) and state DOT transportation plans, government and academic publications, futurist books and predictions, and historical Federal Highway Administration (FHWA) and Census data. This wide variety of sources helped ensure that a diverse range of perspectives was considered in developing the model. The following sections present information from some of the more important references used in developing the model.

2.1 MPO Regional Transportation Plans

Regional transportation plans offer a look at 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. This research focused on incorporating ideas from the Atlanta Regional Commission's (ARC) 2030 and 2040 regional transportation plans, while also looking at trends and objectives of other metropolitan areas' transportation plans. Although the values of the attributes of these other regions' transportation plans such as population growth are not relevant to the Georgia context, reviewing such plans provided an indication of which variables were considered most important in defining future transportation system performance (and thus for this research, future transportation revenues).

2.1.1 Atlanta ARC 2030 Regional Plan (Atlanta Regional Commission, 2007)

Atlanta's 2030 Regional Plan was adopted in its final form in September of 2007. The 2030 plan discusses SAFETEA-LU's planning requirements and how the federal law affected the region's goals. Figure 4 shows the plan's projected spending distribution over the 25-year time horizon, and from this it can be seen that the majority of funding was to be spent on updating and optimizing existing transportation assets.

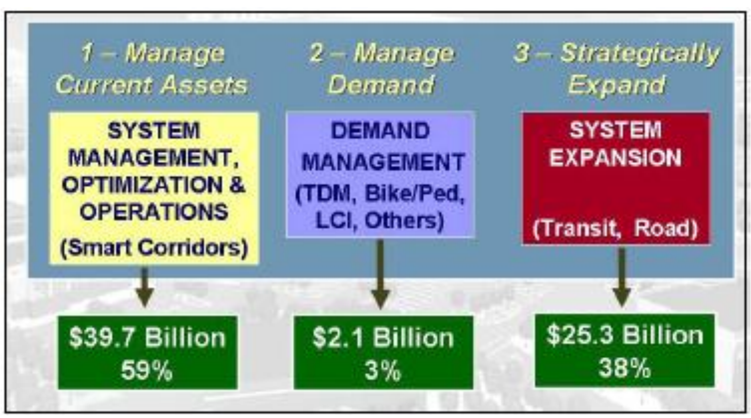

Figure 4: ARC 2030 Regional Plan Priority Areas

The 2030 plan highlighted Atlanta region's rapid growth, as the Atlanta metropolitan area led the nation in absolute population growth from April 2000 - July 2006. The plan then stressed how congestion will continue to grow if population growth continued. The ARC projected a 2030 regional population of just fewer than seven million residents, adding approximately 91,000 persons per year during this time horizon. The plan also projected an increasing percentage of individuals in the 60+ age cohort, as shown in Figure 5.

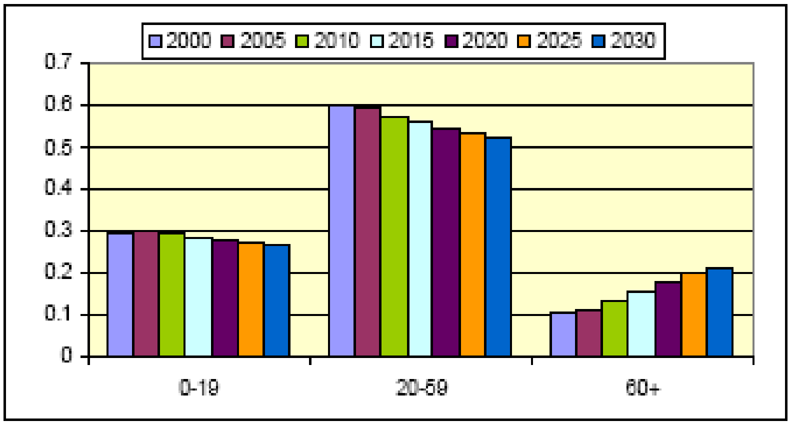

Figure 5: Historical and Projected Age Distribution in Atlanta Region

The 2030 plan references an ARC *Needs Assessment Report*, which stated that interstate highways in the Atlanta region were reaching their carrying capacity, thus prompting the region to pursue a more multi-modal strategy to optimize the pre-existing network. Figure 6 represents the projected increase in travel time based on increases in volume and congestion.

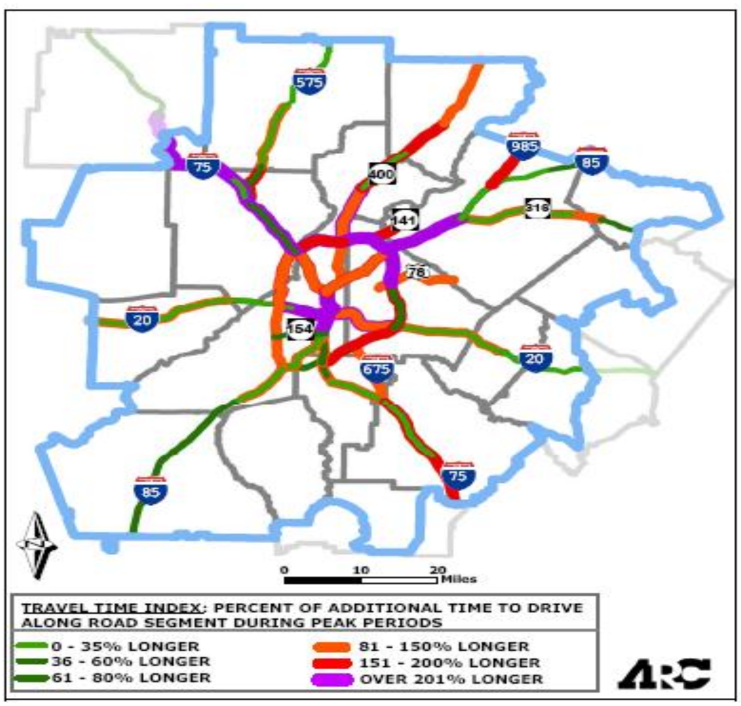

Figure 6: Projected Travel Time Increases in the Atlanta Region (2030)

Finally, the report briefly mentioned the region's plans for expanded transit and bicycle and pedestrian facilities as a means of improving transportation for those who either cannot drive or chose not to drive.

2.1.2 Atlanta (ARC) 2040 Regional Transportation Plan (Atlanta Regional Commission, 2011)

The 2040 Regional Transportation plan, completed on June 22, 2011, is a more in-depth and comprehensive analysis of transportation in the Atlanta area than the 2030 plan. In addition to updated demographic data from the 2030 plan, it also discusses sustainability, and focuses more on bike/ped plans, transit, and investment strategies.

The 2040 plan mentions the following reasons for the Atlanta region's 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, proximity to Fortune 500 companies, premier universities, and the Centers for Disease Control (CDC). Figure 7 shows that the population in the region is projected to reach eight million people in 2040, with the majority of the growth taking place in Fulton and Gwinnett Counties.

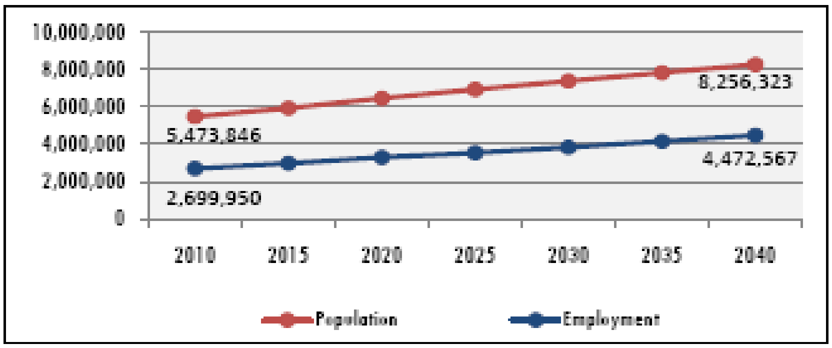

Figure 7: Projected Atlanta-region population through 2040

The plan states that significant growth will also occur in the ten counties that fall within the 20-county air quality non-attainment area, but outside of ARC's boundaries, thus resulting in longer commuting trips in the region's exurbs. Many of these counties are predominantly rural, but are likely to develop as a growing population forces additional land to be consumed. This development is likely to change travel patterns in these areas as well as strain infrastructure, as many of the roads in these areas were not designed for high traffic volumes.

The 2040 plan updates the region's congestion as well as the effect of congestion on the local economy. The impact of this congestion on regional travel times is illustrated in Figure 8, and it shows that area residents will have to dedicate exceedingly more time to travel if no improvements are made.

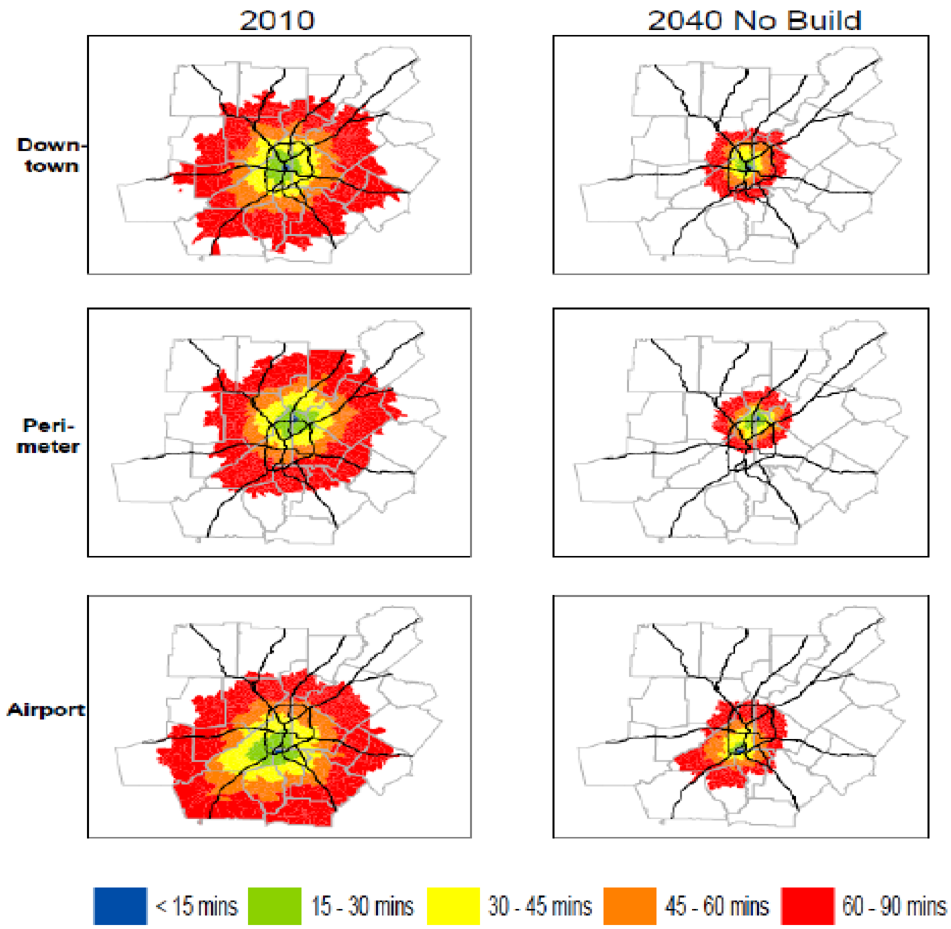

Figure 8: Impact of Congestion on Regional Travel Times in 2010 and 2040 (ARC 2040 Regional Transportation Plan)

As was mentioned in the 2030 plan, the 2040 plan also 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 needs.

In addition, increasing transportation and fuel costs will constrain individuals' housing choices, as transportation costs represent an increasingly higher percentage of their budget. The plan goes on to say 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 inexpensive land translates to costly commutes.

The 2040 plan includes steps to combat congestion and increasing fuel costs and improve the quality of life for its residents. These steps include ideas such as healthier communities and greater accessibility to community resources via improved bike and pedestrian options, implementing a state-of-good repair initiative to ensure that transit and road facilities are maintained, improved connectivity between housing and jobs, improved energy efficiency, and establishing a region-wide economic growth strategy to re-invest in the region's transportation infrastructure.

Finally, the plan also discusses new methods of increasing the region's system capacity such as the newly implemented I-85 High Occupancy Toll (HOT) lanes and other travel demand techniques, new forms of transit such as streetcars and light-rail technology, and identifying specific interchanges that could be redesigned to alleviate bottlenecks throughout the region.

2.1.3 Columbus, Ohio 2030 (MORPC) Regional Transportation Plan (Mid-Ohio Regional Planning Commission, 2008)

Adopted in 2008, the 2030 Columbus (Ohio) 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 ARC's plans in that it more explicitly states an objective of reducing overall VMT. In support of reducing VMT, the Columbus 2030 plan emphasizes sustainable transportation projects such as using a Complete Streets strategy, which encourages walking and biking and helps promote population density. In conjunction with the Complete Streets concept, the Columbus plan re-evaluates walking behavior and outlines a strategy to better incorporate walking behavior with transportation expansion. So, even though the Columbus plan assumes population growth, it explicitly adopts strategies to position this population so as to reduce overall VMT.

2.1.4 Chicago, Illinois (CMAP) 2030 Regional Transportation Plan (Chicago Metropolitan Agency for Planning, 2008)

This version of Chicago's 2030 Regional Transportation Plan was finalized in October 2008. The plan provides very explicit and specific goals and strategies for achieving these goals. Similar to ARC's strategies, the Chicago plan proposes increased walking, biking, and transit usage; real time travel information; and programs to rehabilitate infrastructure. However, Chicago's 2030 plan also includes other directives not mentioned within ARC's plans, including encouraging redevelopment and infill, aggressive parking pricing, locally planned land-use patterns, location-efficient mortgages, and balanced zoning throughout the region to optimize overall travel patterns.

While Chicago is a larger and more transit-friendly region than Atlanta, it is plausible that many of these strategies might be pursued in Atlanta in the coming decades, and thus the impact of such strategies should be considered for the purposes of this research. Strategies such as redevelopment and infill, and better land use patterns would likely reduce VMT and affect fuel tax revenue, although not likely in significant ways.

2.1.5 Minneapolis, Minnesota (Metropolitan Council) 2030 Transportation Policy Plan (Metropolitan Council, 2010)

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

The Metropolitan Council also appeared to be interested in reducing VMT via a variety of measures, and presented many explicit means of achieving such reductions.

2.1.6 Portland (METRO) 2035 Regional Plan (Metro, 2010)

The Portland 2035 Regional Transportation Plan was adopted in June, 2010. The Portland region is known for being a progressive transportation area, utilizing a regional growth boundary and several other innovative measures. It also has an extensive bike lane network, a light rail and integrated streetcar network, and many walkable areas. Because of this, the growth of per capita VMT has been much less than that experienced in comparable sized cities, such that it is now 20% of similar metropolitan regions. In conjunction with this reduction, the 2035 plan had an explicit objective that states "reduce vehicle miles of travel" (Metro, 2010).

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

Many of the other regional transportation plans surveyed for this research list the strategies employed by Portland; however, few U.S. cities have as much experience in actually implementing these strategies. The policies implemented in Portland over the past few decades show that such strategies can result in reduced VMT and thus reduced motor fuel tax revenue (assuming gas taxes are not increased to offset the lowered use of the highway network). When examined holistically, Portland's policies are more innovative and far-reaching than those of almost any other region in the country. Portland Metro's ability to adopt rules that allow them to do so much to reduce VMT is based partly on the state granting them the power due to so. Thus, there are many political factors that would affect whether Atlanta and other regions within Georgia could ever attempt to enact similar policies.

2.2 State Transportation Plans

Three state transportation plans in particular were helpful in identifying factors that could influence future VMT---those for California, Georgia and Texas.

2.2.1 Georgia 2035 Statewide Transportation Plan (Cambridge Systematics, Geostats, Reynolds, Sycamore Consulting, & Dixon, 2006)

The Georgia 2035 Transportation Plan was finalized in January, 2006. Because this plan was completed in early 2006, it did not account for the events of the past six years, including the high fuel prices in 2008 and continued economic recession and accompanying high unemployment rates. Unlike the transportation plans from the MPOs, the statewide plan includes more information about the existing state of transportation assets such as roads, bridges, and airports; however, this information is not considered directly pertinent to projecting motor fuel tax revenue.

One of the strongest VMT indicators for a given area is its population and projected population growth. Figure 9 illustrates the 2035 plan's projected population growth by region within Georgia. It is important to note that the Atlanta region was projected to have the highest rate growth, in addition to being the most populous region.

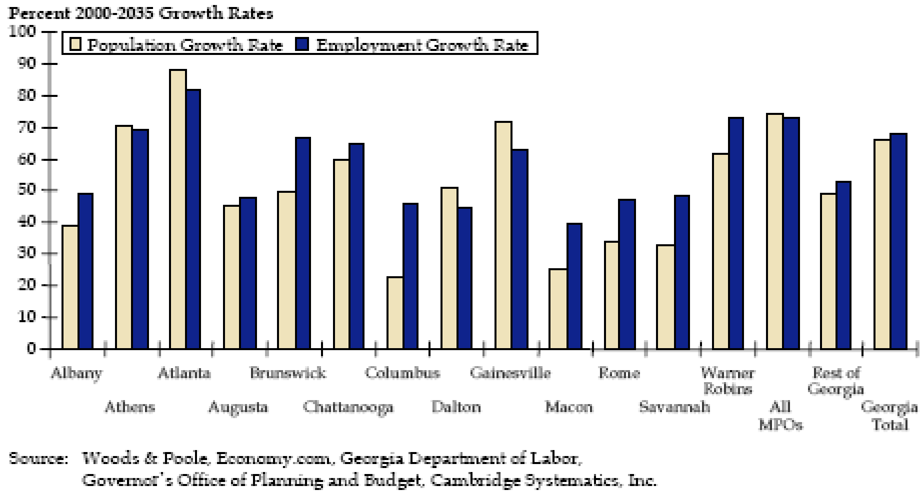

Figure 9: Projected Population Growth (Georgia 2035 Statewide Plan)

The economy is often a large driver of population growth. The Georgia statewide plan identifies the following factors that could affect economic growth: military spending, global recession, increasing fuel prices, corporate outsourcing, and the increase in the number of baby boomers. In hindsight, many of these factors have affected or likely will soon affect the economy in Georgia, based on what has transpired over the past six years. The economic recession, along with increased fuel prices, corporate globalization and the aging of the baby boomers, have had a strong influence on the economic health of the Atlanta region. Incorporating such events into the analysis of future population growth will be important for predicting other future trends such as VMT and fuel tax revenue.

Despite what has happened to the economy in recent years, if one assumes the plan's projected population growth will occur at some point in the future, many of the state's roads will become even 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 capacity increases.

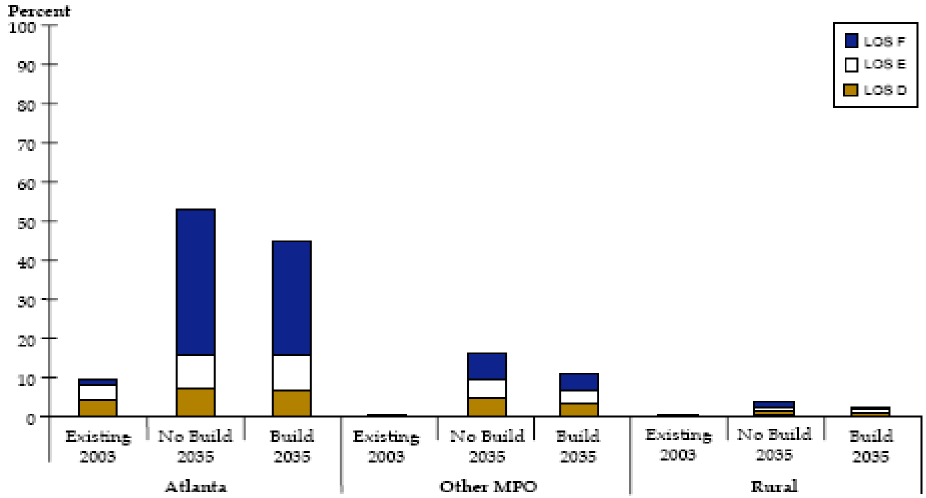

Figure 10: Projected Level of Service in Georgia under Build and No Build Scenarios

Also contributing to a deteriorating level of service on the highway network is increased truck traffic. The 2035 plan predicts that freight traffic (in ton-miles) will increase 171 percent from 2005 to 2035, and that the mode-share for truck will increase.

The 2035 plan also projected future fuel tax revenues. It stated that up to 2005 there was an annual growth rate of 1.33%, which was expected to continue in future years; however, the revenue generation of the past six years given the recession have been far below this projected growth rate.

Because the 2035 Georgia statewide plan is over six years old, many of its predictions and data are out-of-date due to recent economic events. However, the projections of increased population and congestion will likely be at least partially fulfilled over the longer run.

2.2.2 2025 California Plan (Caltrans, 2006)

For the most part, the California 2025 Statewide Transportation Plan addresses many of the same issues as Georgia's plan, including the state of existing infrastructure, population growth, changes in demographics, and projected congestion. However, it does identify some issues that are not mentioned in Georgia's 2035 plan, one of these being technology.

California is at the forefront of transportation technology with the state fostering many different experiments with new vehicle, infrastructure and fuel technologies. Technology may change the way people drive via new vehicle types such as plug-in hybrid vehicles, electric vehicles or fuel-cell vehicles; it may change the way vehicles interact, using sensors and short range communication for safety improvements; and it may change how frequently people drive, through telecommunication substitution for travel.

California's state transportation plan also discusses land use patterns and the housing-employment mismatch that occurs when affordable housing is not available. In California this occurs primarily 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 levels in the country.

The technology advances discussed in California's state transportation plan were perhaps the most relevant and unique factor mentioned in the plan. Modern technology evolves rapidly, and predicting the technology that will be present in vehicles and embedded in the road infrastructure in one or two decades is difficult. For the purposes of this report, it is more important to understand how implementing these technologies could affect VMT versus which technologies are put into place.

2.2.3 Texas 2035 Statewide Transportation Plan (Texas Department of Transportation, 2010)

The 2035 Texas statewide transportation plan was completed in 2010 and addresses many of the same concerns that were present in both the Georgia and California plans. Some of the factors mentioned that influence travel demand were population growth, age distribution, employment trends, disposable income, economic disruptions, transportation network capacity, and major employment relocations. In addition to these variables, the plan also examined five broader topics that could change the landscape of transportation in Texas.

The first of these topics was changing energy sources and how these changes affect travel behavior. The plan stated that the state's residents and transportation officials need to consider the impact of increasing fuel prices, alternative fueled vehicles and their effect on infrastructure, more efficient vehicles, and potential alternatives to the motor fuel tax and how these alternatives affect transportation patterns. It predicted that if average household costs for transportation were to remain stable over time even with the use of alternative fuels, that transportation demand would likely increase rapidly; however, it also predicted that if costs increased significantly or if costs were unstable, that travel demand could decrease.

The second topic was climate change. The plan mentioned that increasing temperatures could bring a rise in sea level and more extreme events such as hurricanes and floods. These extreme events could disrupt transportation activity such as air flights, seaports, and rail movements, in addition to flooding major roads. An increase in the number and intensity of hurricanes could also result in more evacuations, requiring more disaster-relief revenue and resulting in fewer miles driven with a disrupted economy. Intense heat could also weaken pavements more rapidly, resulting in more construction costs and travel delays due to construction.

The third topic was urban livability and sustainable living. Texas' plan discusses how downtown revivals and 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.

The fourth topic was changing personal travel behavior due to changes in the transportation system. This included 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. Such measures are already in place in the Atlanta region and are mentioned in ARC's 2040 regional transportation plan.

The final topic was vehicle and system technology. As was mentioned in California's statewide transportation plan, this factor includes such strategies as intelligent transportation systems (ITS), GPS, improved traffic signal timings and other travel demand management measures that could reduce congestion and increase capacity. Such advancements are also likely to be seen in Georgia and would result in similar transportation benefits.

In addition to these five factors, the Texas 2035 Statewide Plan lists forces affecting VMT growth in Texas. These forces were considered to be: population growth, commercial freight, the quantity of travel per person, international imports and exports, and how much tourist and business opportunities expanded in Texas.

The Texas 2035 statewide transportation plan provides a holistic and 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 Outputs (Atlanta Regional Commission, 2010)

Regional Economic Modeling Inc. (REMI) is a forecasting tool that projects variables such as population, migration and employment. This software is used by the ARC, and its model outputs were used as sources of information for projecting key variables relating to VMT growth. The REMI model projected variables for the ten-county metro region, the twenty-county non-attainment region, all other counties in Georgia and the entire state.

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

Figure 12 shows the breakdown in projected population by location. In Figure 12, core counties include Fulton, Dekalb, Gwinnett, Cobb, and Clayton, Henry, Rockdale, Douglas, Fayette, and Cherokee Counties; "surrounding counties" represents the other ten counties in the Atlanta non-attainment area. As can be seen from the figure, the core and surrounding counties of Atlanta are expected to grow faster than the other counties in the state; however, the entire state's population is expected to grow rapidly.

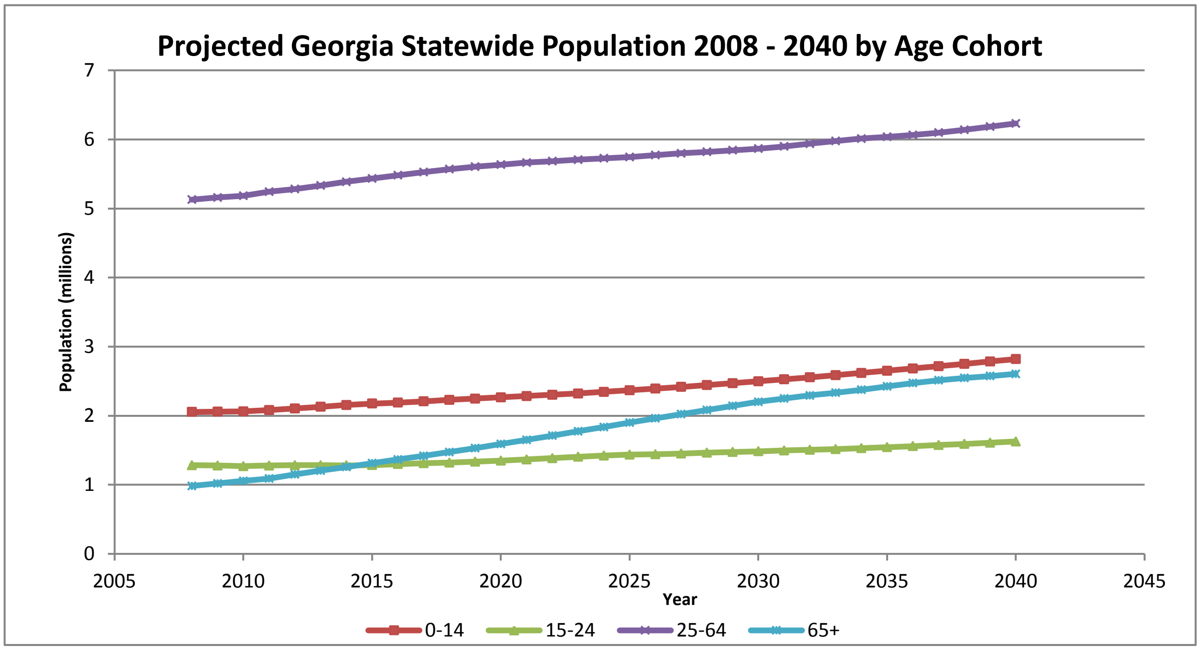

Figure 11: Projected Statewide Population Growth by Age Cohort (ARC REMI Model)

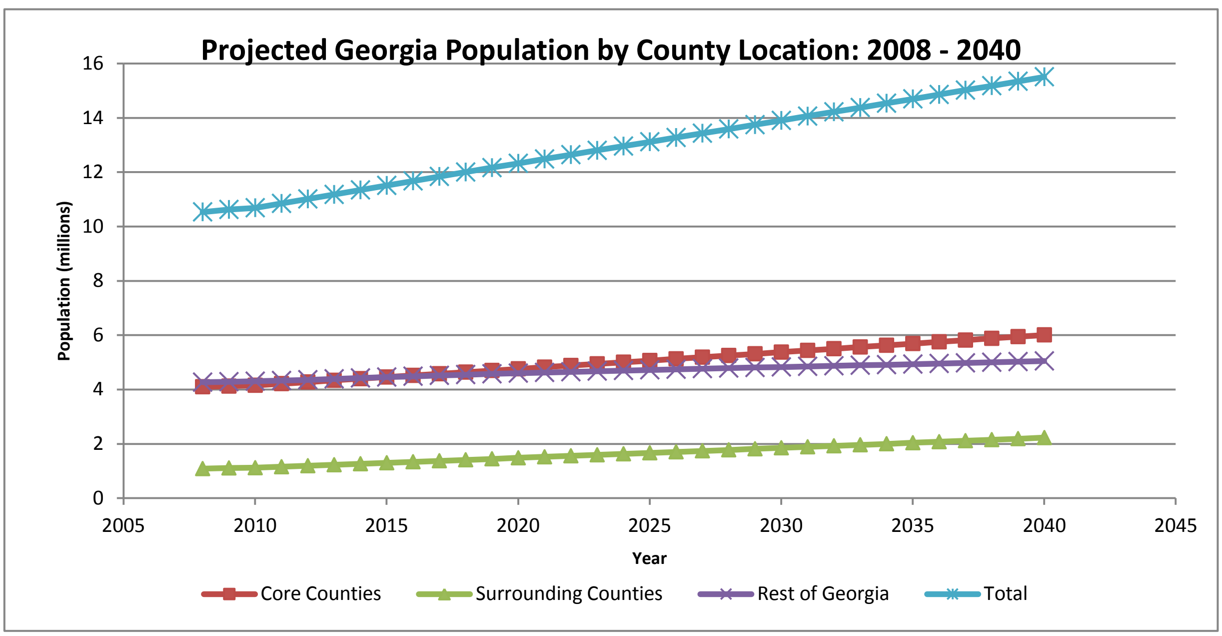

Figure 12: Projected population in Georgia by County from 2008 - 2040 (ARC REMI Model)

Figure 13 illustrates the economic output of the REMI model. It shows projected 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 in GDP.

Overall, the REMI model outputs were valuable for this research as they provided Atlanta and Georgia-specific projections for the next 30 years. These projections were used to develop the motor fuel tax revenue model.

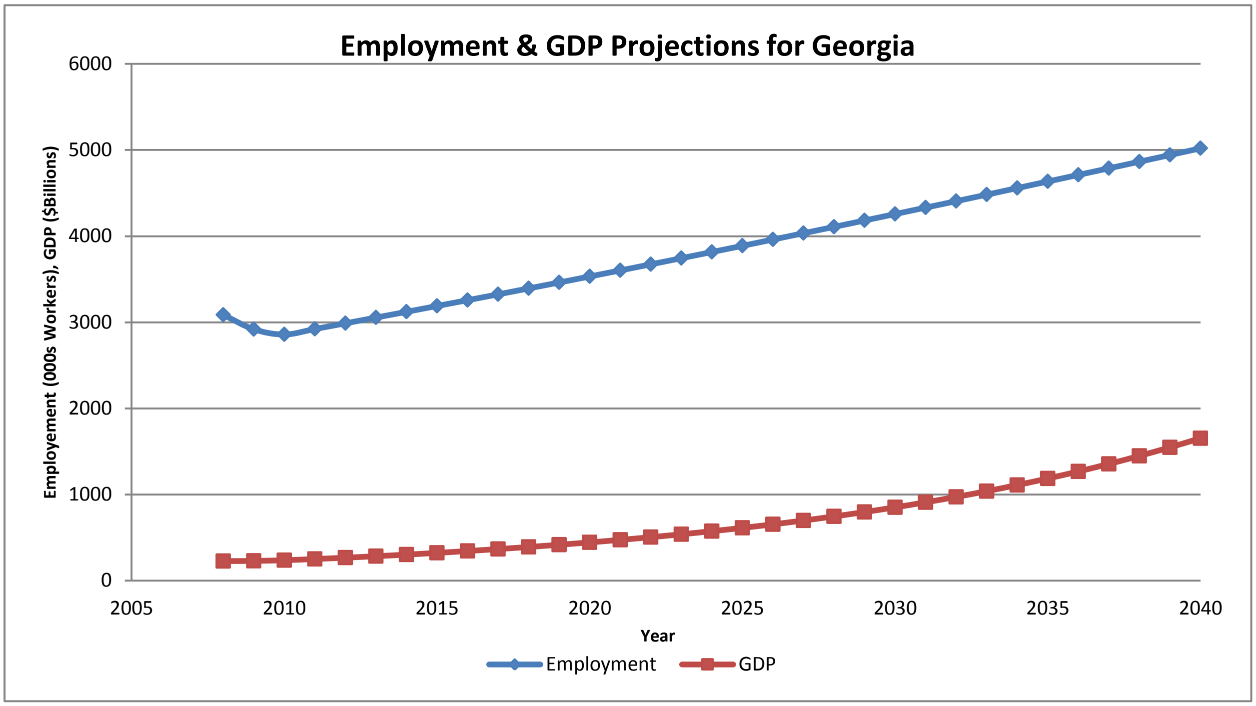

Figure 13: Projected Employment and GDP for Georgia 2008-2040 (ARC REMI Model)

2.4 Government Reports

2.4.1 NCHRP Project 20-80 Task 2: Long Range Strategic Issues Facing the Transportation Industry (ICF International, 2008)

This report, prepared by ICF International, Inc. in October, 2008, developed a framework to identify future trends and challenges to both prepare the transportation industry for changes and better shape the nation's transportation future. In creating this framework, the authors assumed a 50-year time horizon, specifically looking beyond those issues currently facing the industry. Five key forces were identified that encompassed various factors and trends. The first of these forces is government and politics, including the potential for changing transportation financing mechanisms and how this would affect the construction and maintenance of transportation assets. Extremism and/or terrorism and how such acts or the threat of such acts could affect the way infrastructure is designed, operated, and protected, and the costs associated with these actions were also discussed.

The second force was economics, and in particular economic activity that drives transportation. As the world's population and transportation activity increases, it is important that transportation system efficiency improves to ensure reasonable mobility. Also, because of the global economy, development in foreign markets like China and India can change the volume of transportation routes within the United States, increasing the need for efficient movement of goods.

Demographics and societal choices, the third factor, were also expected to influence transportation in the coming decades. Population growth, migration, the growth of certain age cohorts, and urban development patterns will all affect travel behavior and VMT in coming years. The aging of the baby boomer generation will cause the percentage of the elderly to grow rapidly. This could result in a significant number of people transitioning to a soft retirement, exhibiting a different travel behavior than both full-time employees and stay-at-home workers. Evidence also suggests that young people may not enter the work force as quickly in coming decades, choosing instead to travel or volunteer immediately after school. As people marry later, changes in family structure are also likely to occur, with fewer married couples living together and having fewer children.

Environmental and energy constraints, another factor, could also affect travel. Increased competition for natural resources and increasing fossil fuel prices could force society to switch to 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.

The final force was technology. Technology could induce many changes across the transportation landscape, ranging from medical advancements to computing to vehicle technology. Medical advancements could dramatically extend lifespan, resulting in increased populations and greater VMT. Computing advancements could make it easier to telecommute via more personal long-distance interactions. Vehicle technology could advance vehicle-to-vehicle and vehicle-to-wayside communications to improve vehicle safety.

Each of these forces could have a significant impact on VMT in Georgia. While some points of the demographic and governmental factors are specific to Georgia, changes in transportation policy at the federal level will still impact transportation in Georgia. Technology advancements, economic swings, and environmental constraints could also all affect the travel behavior in Georgia.

2.4.2 NCHRP 20-83A Long-Range Strategic Issues Facing the Transportation Industry Workshop (American Association of State Highway Transportation Officials Standing Committee on Research, 2010)

This workshop was a follow-up to the report described above. The workshop brought people from many different sectors outside of transportation together to consider the changes resulting from an aging population, fuel shortages and changes in the way we use current fuels, climate change, pollution and environmental concerns, changing funding strategies and partnerships between public and private entities, and a changing economy that is more global. The intent of the workshop was to think beyond current understandings of transportation and the factors that influence system performance, and to contemplate future events or characteristics of society that would clearly affect mobility. Due to the broad scope of the workshop, only those topics that would likely influence VMT growth in Georgia are presented here.

Several of the speakers discussed medical advancements and how these would not only prolong life, but also keep humans functioning at a high level for a longer period of time. These advancements stem from the human genome project, the role of genetics in treating cancer, and healthier people through the process of genetic selection. The workshop then discussed the fact that as the baby boomer generation ages, they may move closer to destinations so that they can take transit or paratransit. Thus, longer life spans may not result in significantly increased VMT due to shorter trip lengths.

Another area of focus at the workshop was technology. Some examples included a “personal brain” that can remember appointments and where one needs to be at all times, akin to the newest iPhone’s Siri. This device could reduce VMT by optimizing travel patterns and routes. Another technology discussed in the report was nanotechnology. Nanotechnology could impact many different materials, including pavements, making them last longer and reducing the frequency for construction and delays. Autonomous vehicles and vehicle-to-vehicle communications were also considered likely, increasing roadway capacities and possibly improving safety. One participant noted that improvements in superconducting technology will be crucial for the continued development of electric vehicles, a smart grid, and high speed trains. Increased prevalence of open data systems will help provide more real-time travel information, further optimizing users' travel patterns. Real-time data may soon extend to other data sources such as weather, traffic accidents, and even pollution, allowing users to react more quickly and save time on their trips.

Policy and infrastructure investment was another topic discussed at the workshop. One of the points made was that transportation must be thought about more broadly and that there are now more stakeholders that have to be satisfied. It was argued that transportation spending should be more flexible to support a wider range of modes, and that more focus should be given to freight. New methods of revenue collection will need to be devised and implemented. Governments and municipalities will need to be more "nimble" to react to changing needs without long periods of developing legislation.

Many of the ideas discussed in the workshop were far-reaching and may not be achieved for decades, if realized at all. However, some of these concepts such as medical advancements and transportation financing and governance, can occur incrementally, and thus could have an impact on VMT and fuel tax revenue in Georgia during the next two to three decades.

2.4.3 Commuting in America III: The 3rd National Report on Commuting Patterns and Trends (Transportation Research Board, 2006)

This extensive report catalogues travel trends in the U.S. during the late 20th and early 21st centuries. These trends included trip frequency, trip length, trip duration, temporal trip distribution (throughout the week and day), and mode share among others. These trends were further broken down by region (Midwest, Southeast, etc.) and in some cases, by major metropolitan area. The report also included specific commuter flow information, such as how many individuals traveled from the inner city to suburbs.

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

Because this report was published in 2006, it is somewhat dated because it did not reflect the influence of economic recession and increased fuel prices. However, it provides perhaps the best summary of historical travel trends available in one source. *Commuting in America III* was useful in establishing a baseline of how travel differs among regions and groups.

2.4.4 2017-2025 CAFE Standards Supplemental Report (Environmental Protection Agency and National Highway Traffic Safety Administration, 2011)

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

This national program would apply to passenger cars, light-duty trucks, and sport-utility vehicles. Such a program would allow vehicle manufacturers to produce one light-duty fleet for both the EPA and NHTSA mandated fuel economy improvements and emissions reductions. The EPA's goal to achieve a standard of 163 gram/mile of emissions in 2025 equates to an equivalent 54.5 mpg if all of these reductions were achieved with increases in fuel economy, which would mean drastic fuel economy improvements. In developing these projections, the EPA and NHTSA worked with vehicle manufacturers to discuss the feasibility of such improvements and to ensure that the improvements would be derived from vehicle technology improvements.

Much of this supplemental report discusses the specifics of the proposed emissions reductions, the timeline and methodologies for achieving these reductions, and the political processes 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 vehicle manufacturers.

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 (2016-2025)

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

Because the fuel economy values shown in Table 1 are national level estimates and because Georgia does not have its own fuel economy standards, it can be assumed that these values are a credible source when attempting to project future fuel economy.

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

This report analyzes the different incentives that each state has provided to residents and vehicle manufacturers to entice residents to buy electric or hybrid vehicles. 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 impact 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 the Clean Cities program. It then uses these investment projections to predict how many electric vehicles will be purchased in each state in the years 2011-2015.

This report is helpful in that it not only provides a credible estimate of electric vehicles in Georgia from 2011-2015, but also identifies the factors that affect electric vehicle deployment. If data for these factors can be found, they could act as inputs to predict electric vehicle deployment.

2.4.6 Annual Energy Outlook 2011 with Projections to 2035 (Energy Information Administration, 2011)

This report, published by the U.S. Energy Information Administration (EIA), projects the supply and consumption of various energy sources up to 2035. In projecting these consumption rates, the outlook also identifies legislation at both the state and federal levels that has the potential to affect these predictions. It should be noted that Georgia was one of 20 states that did not mandate any renewable portfolios.

The report also looked at several key issues using a baseline case, a no sunset case, which extends current renewable energy incentives and subsidies, and an extended policy case, which adopts even more stringent renewable assumptions. Figure 14 illustrates the projected consumption of transportation fuels through 2035 using these different cases.

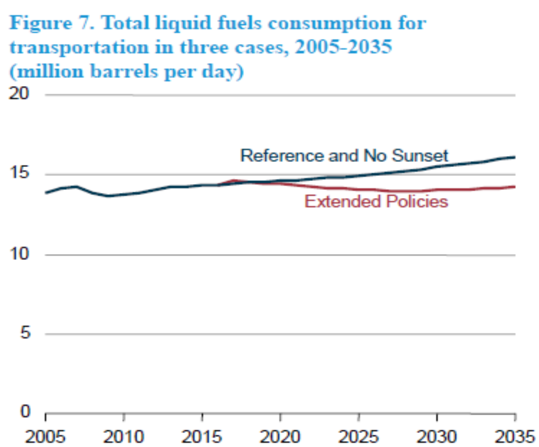

Figure 14: Projected Transportation Fuel Usage Under 3 Scenarios (EIA 2011 Energy Outlook)

The report also uses 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 15 shows these projected costs.

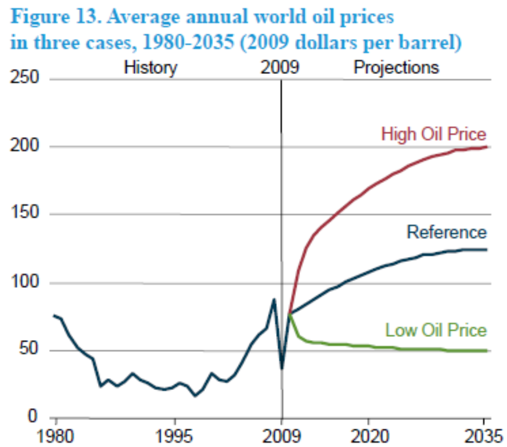

Figure 15: Projected Oil Price under 3 Scenarios (EIA 2011 Energy Outlook)

Other projections in the report include vehicle fuel economy based on varying growth rates of the CAFE standards, vehicle market share per vehicle type and vehicle price, fuel economy projections for medium-duty and heavy-duty trucks, and annual VMT per licensed driver as shown in Figure 15. From Figure 16, one can see that annual VMT per licensed driver is expected to increase during the coming decades. This prediction goes against the stated objective of many of the MPO regional transportation plans that were surveyed.

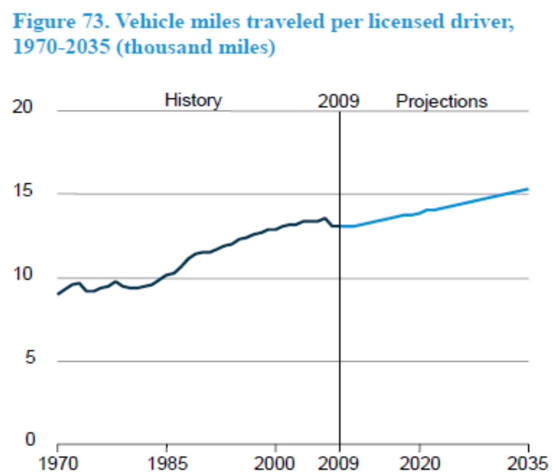

Figure 16: Projected Annual VMT per Licensed Driver (EIA 2011 Energy Outlook)

Much of the rest of the report was dedicated to the specific technologies that would affect energy consumption or fuel economy and examined energy trends in the residential and industrial sectors, as well as emissions projections.

Overall, this report provides a wealth of credible projections at the national level through 2035 across multiple sectors, vehicle types, and energy sources. This report was used to establish baselines for model predictions and estimates across multiple variables in the energy sector.

2.5 Academic Publications

2.5.1 The Motor Use Fuel Tax in Georgia: Collection Efficiency, Trends, and Projections (Clarke, Brown, & Hauer, 2010)

This paper was written in December 2010 by Clarke, Brown and Hauer at the Carl Vinson Institute of Government at the University of Georgia, and its objective was to determine whether there is a gap between the motor fuel tax revenue GDOT should collect based on highway usage and the revenue it actually collects. Secondary objectives investigated the impact of Georgia's relatively low fuel tax on margins and the state's fuel tax revenue as compared to other states.

In assessing historical fuel tax revenue trends, the authors looked at historical trends and 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. In 2008 when fuel prices rose abruptly, the opposite occurred and motor fuel tax revenue increased. Looking forward, the authors predicted VMT to increase at 1.8% per year and fuel tax revenue to increase 2.4% annually.

Although much of this paper focuses on fuel tax evasion and comparisons to other states' fuel tax rates, many of the intermediate goals are very similar to the objectives of this research as the authors predicted future motor fuel consumption, VMT and fuel tax revenue. While this research is creating a unique model, some of the input values and sources referenced in the paper will be useful. The paper is especially useful as it is includes the effect of 2008's fuel price increases and the economic recession.

2.5.2 Forecasting Highway Revenues Under Various Options (Agbelie, Bai, Labi, & Sinha, 2010)

This paper was published in October of 2010 at Purdue University by Agbelie, Bai, Labi and Sinha. Their research effort was similar to the research reported on in this report, although applied to Indiana. Also, this paper focused more on predicting Indiana motor fuel tax revenue under different revenue strategies, such as indexing fuel taxes to inflation or using a VMT-based tax, whereas the model developed as part of this project allows model users to adjust different model inputs under the same revenue collection framework to help GDOT interpret how different factors affect future motor fuel tax revenues.

The Agbelie et al. model stratifies automobiles into class by automobile, combination truck, light duty truck, single unit truck, bus and motorcycle, and projects VMT for each of these vehicle classifications independently using income, GDP and driver age population as inputs.

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

The number of vehicles in future years was projected using input factors of income, GDP, and driving age population. After the number of vehicles, VMT and fuel economy was projected, fuel consumption for a given model year vehicle type was calculated 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 baseline (current), VMT-based fees and by adjusting fuel taxes to inflation. Elasticities were used when other revenue sources were estimated such as additional fees or tolls.

This 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 a single state. It was also helpful in that many of the same data sources used in the paper led to the identification of similar data sources for predicting motor fuel tax revenues in Georgia.

2.5.3 The Future Isn't What It Used To Be: Changing Trends and Their Implications for Transport Planning (Litman, 2011)

This report, written by Todd Litman at the Victoria Transport Policy Institute, examines 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.

Many of the trends listed within the report produce conflicting effects on VMT growth. The trends identified 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. 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 off of other trips. However, these other trips, such as children's activities, are also increasing in frequency, which increases VMT.

Some of the trends identified that would likely decrease VMT were on-line purchasing, a saturation in automobile ownership, decreasing automobile ownership among those aged 16-19, and increased trip chaining. On-line purchasing allows individuals to shop without accruing VMT from shopping trips. Saturated automobile ownership implies that VMT growth would likely stabilize, as the percentage of individuals owning a car would show no net increase. 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 17 illustrates the decreasing percentage of teenagers with a driver's license.

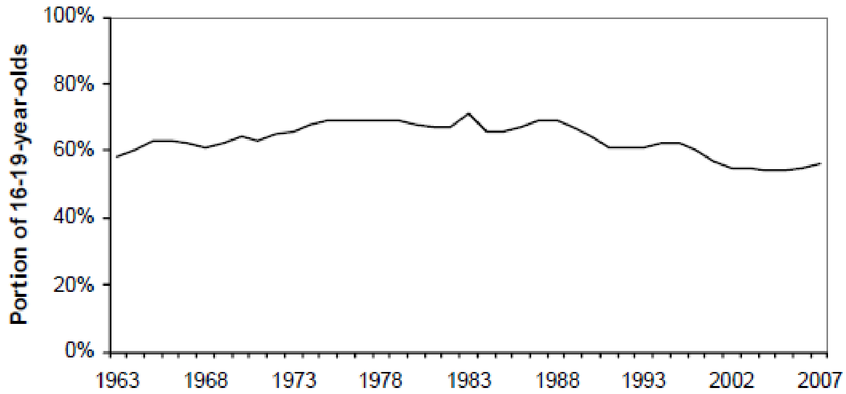

Figure 17: Percentage of 16-19 Year Olds with a Driver's License from 1963 to 2007 (Litman 9)

Litman also includes a table that predicts how different factors will impact travel demand. This table is shown in Figure 18.

Table 4 **Factors Affecting Future Vehicle Travel**

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.

Figure 18: Factors Affecting Future Vehicle Travel (Litman 31)

Many of the factors and trends discussed in Litman's report are similar to those outlined in the MPO and state transportation plans as seen in sections 2.1 and 2.2. Each of these factors was considered both individually and interactively in how they impact VMT.

2.5.4 If Cars Were More Efficient Would We Use Less Fuel? (Small & Van Dender, 2007)

This article was written in the fall of 2007 for the University of California's transportation research periodical by Kenneth Small and Kurt Van Dender and analyzed recent fuel price elasticities in California to evaluate the rebound effect. The rebound effect describes how fuel economy improvements can counteract fuel price increases. Understanding this concept is important when developing a model that must take into account fluctuations in fuel price.

The article describes two parts to driver response to increasing fuel prices. First, VMT decreases by a given percentage due to increasing fuel prices. If these prices are maintained, the market will likely respond by producing more fuel efficient vehicles. These more efficient vehicles allow drivers to travel the same distance with 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 in increased VMT. The magnitude of this rebound effect impacts how effective CAFE standards that mandate increased fuel economy can be at reducing emissions.

The article explains that the magnitude of the rebound effect declines as income rises, as time becomes more important than fuel costs, and that the magnitude increases as fuel costs rise and they become a more significant factor. The authors believe that the rebound effect will continue to decline with increasing urbanization, as the time costs associated with congestion dominates fuel costs. The article concludes by saying that elasticities have continued to decline into the 21st century and that the rebound effect was less than 6%. However, it should be noted that this article was published in 2007 and thus does not account for the more dramatic increases in fuel economy that were seen in 2008.

2.6 Books

2.6.1 Transport Revolutions (Gilbert & Perl, 2010)

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 affected the transportation landscape. 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.

In conjunction with these projections, Gilbert and Perl also provide recommendations for how to reduce global energy consumption in the timeframe. Although many of their predictions are aggressive for a now 13-year timeframe, they may be more realistic for more distant projections. 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.

Transport Revolutions provides a strong foundation for understanding how energy and transportation interact, as it presents a wealth of information on current energy production and consumption. Gilbert and Perl also project future energy use and travel behavior, albeit with aggressive predictions, that can be considered along with the projections from other sources.

2.6.2 $20 Per Gallon: How the Inevitable Rise in the Price of Gasoline Will Change Our Lives for the Better (Steiner, 2009)

In this book, Steiner predicts what would occur as the price of gasoline increases from $4 to $20. Each chapter projects the incremental change given a $2 increase in gas price. Although it is unlikely that fuel prices will reach $20 in the near future, $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.

This book was helpful in understanding the potential changes that could accompany various tiers of fuel price increases and could be helpful in understanding that people's psychological response can vary significantly over a small price threshold. 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 (Kotkin, 2010)

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. 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. Kotkin also projects that polycentric cities will become the norm and that a region's main downtown will become less and less vital.

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 those in the Great Plains and rural Georgia. Such employment patterns would likely reduce VMT in urban 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 will influence individuals' future housing choices.

2.7 Other Sources

The other sources used in creating the model were mainly databases. They included the 2009 National Highway Travel Survey (2009 NHTS), U.S. Census Bureau data including the 2010 Census as well as the 2009 American Community Survey, and data from the Federal Highway Administration's (FHWA) Highway Performance Monitoring System (HPMS). The 2009 NHTS did have associated reports and documentation to explain how the survey was structured and undertaken and to explain a variable dictionary when using the database. There was no literature associated with the data obtained from the U.S. Census Bureau or the HPMS database.

The 2008 and 2009 GDOT funding brochures and GDOT 2009 report were also surveyed in order to determine GDOT’s 2009 motor fuel tax revenue.

Chapter 3: Model Development

3.1 Sources & Initial Model Structure

Many of the sources discussed in Chapter 2 were used to identify which factors impacted motor fuels tax revenue by assessing how they affected VMT, vehicle fuel economy and long-term fuel prices. Surveying many different documents that were diverse from both a geographic and source perspective resulted in a more global perspective of those factors that influence fuel tax revenue prior to developing a model. This knowledge was helpful in calibrating and validating the model.

In order to create the model, a recent Georgia-specific travel database was critical. Ideally this database would provide detailed household-level information such as income, persons per household, and vehicles per household, travel information such as trips per day, miles traveled, and vehicle information, such as vehicle age and fuel economy. However, obtaining a survey that was both recent and Georgia-specific was difficult. The ARC conducted a travel survey in 2001-2002 and had another scheduled for late 2011, but unfortunately the results of this survey were not available for the release of this model and report. Other states and MPO's have conducted recent travel surveys; however, this data was not local and was thus not considered relevant. After searching and considering all of the constraints and options, the 2009 National Household Travel Survey (NHTS) database was selected. Figure 19 shows the progression of selecting some of the more important sources.

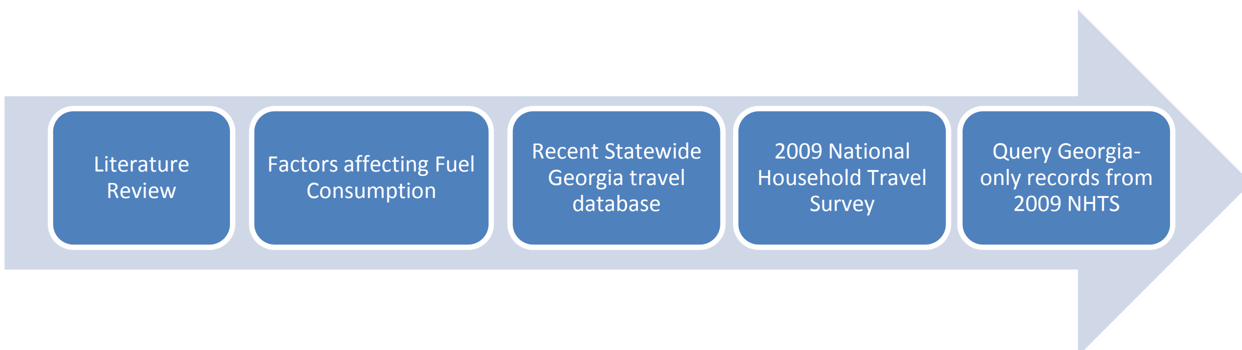

Figure 19: Data Search Process

Although the NHTS was a national survey, it drew mainly from 16 different states. Over 7,000 household and 15,000 vehicle records were from Georgia. Microsoft Access was used to query only those records that were from Georgia and contained valid data. The 2009 NHTS included personal data such as age and gender, household data such as income, persons per household, vehicles per household, and MSA population, and vehicular information such as age and fuel economy. The dataset also had travel information such as trips per day and VMT. Annual VMT data was tabulated from daily or weekly travel information if annual readings were not provided, thus the actual VMT information used within the model is limited.

Other data used throughout the modeling process was obtained from the U.S. Census Bureau and the FHWA. Census data was used to extrapolate average values obtained from the 2009 NHTS database to the state level as well as in model calibration. The FHWA data was used in calculating, calibrating, and projecting freight VMT, as well as observing historical VMT trends. The National Transit Database (NTD) was used in tabulating transit VMT.

3.2 2009 VMT & Revenue Validation Methodology

The model was validated by estimating 2009 motor fuels tax revenue. The year 2009 was chosen due to the constraint of having already selected the 2009 NHTS, thus the 2009 value of all of the other variables included in the model would need to be used. Just as was shown in Figure 2, total fleet VMT and the average fleet fuel efficiency can be used to calculate the total amount of fuel consumed for a given fleet. Figure 1 in turn illustrates how the total number of gallons consumed and the local fuel price can then be used to calculate the sales and excise motor fuels taxes and thus the total motor fuel tax revenue.

In the model, the fleet was split into personal, freight and transit categories, with the freight category further split into single unit and combination trucks. This categorization was made in order to provide greater revenue source transparency within the model and more model inputs to the various model users. In addition, the data sources for each of these categories were quite different, and each fleet had significantly different VMT values and fuel economies. After splitting the fleet into categories, the VMT and fuel economy for each fleet category were estimated.

3.3 Personal Fleet Revenue Calculation & Methodology

Modeling personal fleet VMT was challenging due to the number of factors that impact household travel decision-making. These variables include: persons per household, vehicles per household, household income, age, housing location, and other demographic factors. Figure 20 outlines the thought process for selecting the main household decision making variable with respect to impact on VMT.

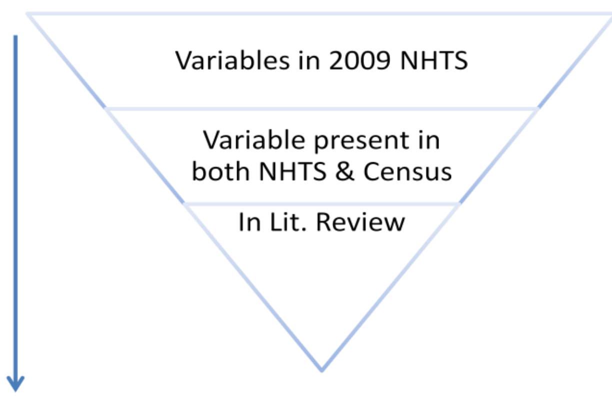

Figure 20: Thought Process for Selecting Main Household Decision-Making Variable with Respect to VMT

3.3.1 Personal VMT Calculation

It was necessary to select a variable present in both the 2009 NHTS and the U.S. Census Bureau's 2009 database (many of the 2009 values were extrapolated using Census values and values from the American Community Survey). Presence in both of these databases was required to extrapolate average VMT values obtained in the Georgia 2009 NHTS records to the state level, of which roughly 7,000 households in Georgia were sampled. In extrapolating personal VMT, the data from a potential variable was stratified into various bins. For example, if vehicles per household was chosen as the main explanatory variable, then an average VMT for households with 1 vehicle, 2 vehicles, 3 vehicles, etc. was calculated using the 2009 NHTS database. This average VMT per bin or grouping would then be multiplied by the total number of households matching the given bin's criterion in Georgia (for example the total number of households in Georgia with 1 vehicle, 2 vehicles, 3 vehicles, etc.). The number of households satisfying this data was obtained from the Census data. Table 2 illustrates this multiplication process, which is similar to matrix multiplication.

Table 2: Generic Example of Personal VMT Calculation using Matrix Multiplication

<table>
<tr><td colspan="6">Generic Statewide VMT Extrapolation Example</td></tr>
<tr><td rowspan="6">Households per Group (ACS)</td><td colspan="5">VMT per Group for Generic Category (NHTS Data)</td></tr>
<tr><td>Households/ VMT</td><td>Group 1 Avg VMT</td><td>Group 2 Avg VMT</td><td>Group 3 Avg VMT</td><td>Group n Avg VMT</td></tr>
<tr><td>GA Households in Group 1</td><td>Group 1 State VMT</td><td></td><td></td><td></td></tr>
<tr><td>GA Households in Group 2</td><td></td><td>Group 2 State VMT</td><td></td><td></td></tr>
<tr><td>GA Households in Group 3</td><td></td><td></td><td>Group 3 State VMT</td><td></td></tr>
<tr><td>GA Households in Group n</td><td></td><td></td><td></td><td>Group n State VMT</td></tr>
<tr><td colspan="6">Sum of highlighted cells is the total personal VMT driven by Georgia households</td></tr>
</table>

After calculating VMT with multiple variables, household income was selected as the main explanatory variable for multiple reasons. First, income was stratified into 8 bins in the 2009 NHTS, which was significantly more bins than other variables such as vehicles per household (3) or persons per household (5). This greater stratification allowed for greater precision when calculating VMT. Furthermore, income could be correlated to other potentially useful variables such as vehicle age, fuel economy and even economic forecasts. Figure 21 compares average household VMT by income cohort using 2009 NHTS data and Table 3 shows how many households fell into each income cohort in 2009 from Census data.

Table 3: Households per Income Cohort in Georgia in 2009 (U.S. Census Bureau: American Community Survey)

Total households in Georgia by Income (2009)	3,469,250
Less than $10,000	309,460
$10,000 to $14,999	218,442
$15,000 to $24,999	404,891
$25,000 to $34,999	382,966
$35,000 to $49,999	505,170
$50,000 to $74,999	631,944
$75,000 to $99,999	403,497
$100,000+	612,880

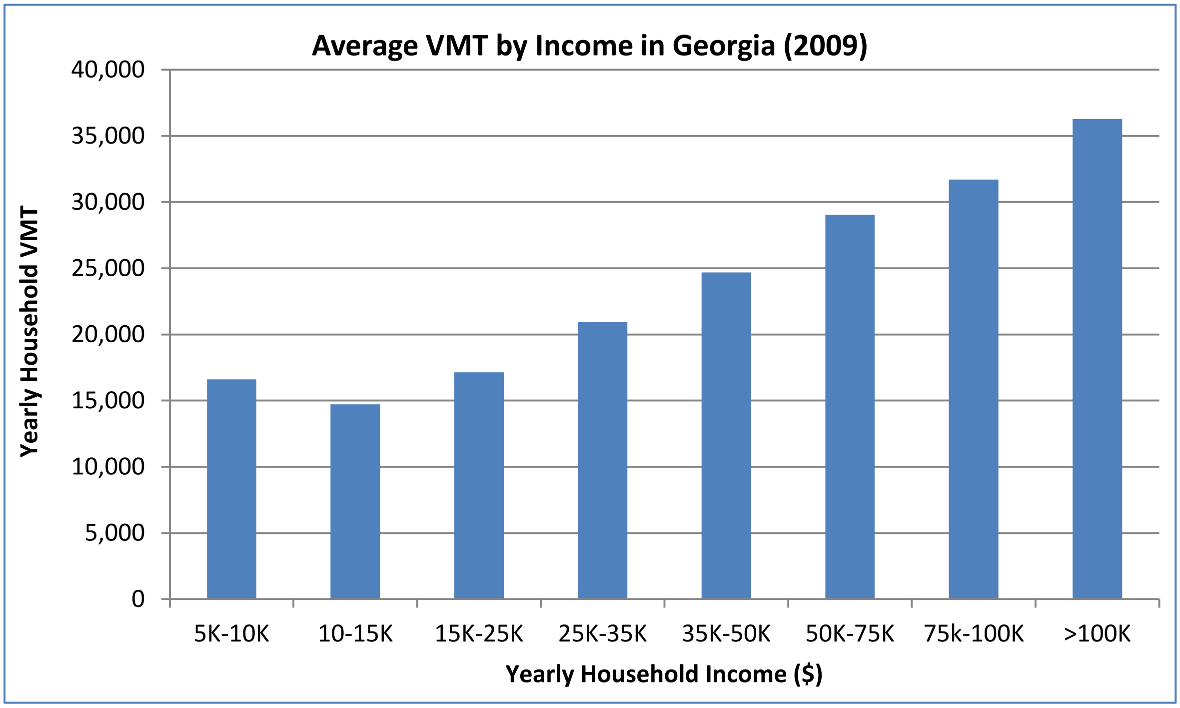

Figure 21: Average VMT by Income Cohort in Georgia in 2009 (2009 National Household Travel Survey)

One can see from Figure 21 that there is a relatively linear increase in VMT as compared to income. This consistent increase was another reason that income was selected to be the main explanatory variable in calculating personal VMT. Table 4 uses the methodology previously outlined in Table 2 and the data shown in Table 3 and Figure 21 to calculate the total VMT for Georgia households in 2009.

Table 4: 2009 Personal VMT Calculations by Income Cohort for Georgia Households

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	309,460	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 4 shows that this calculation methodology resulted in an estimated total personal VMT in Georgia of 87.92 billion vehicle miles. A limitation of this estimation method is that it only accounts for VMT from those households in Georgia and does not account for miles driven in Georgia by households in other states. Thus, the miles attributed to households in other states driving through Georgia would not register in this method. Conversely, miles driven by Georgia households in other states would be counted as miles for Georgia. Intuitively, due to Georgia's tourism industry and location just north of Florida, a major tourist attraction, more miles would likely be driven in Georgia by vehicles registered outside of Georgia than vice-a-versa, and thus it was expected that personal VMT estimated with this method would likely underestimate personal VMT, especially when compared to estimates made from actual road use.

3.3.2 Fuel Economy

In order to calculate total fuel consumption and thus motor fuel tax revenue from personal vehicles, the fuel economy of personal vehicles had to be determined. However, instead of calculating an overall average fuel economy or even an average by vehicle type (car, truck, SUV, etc.), this model distributes vehicles by model year. The 2009 NHTS provided data for vehicle age and from this the distribution of VMT by vehicle age was calculated. Figure 22 shows the distribution of VMT by vehicle age as a percentage of total 2009 NHTS VMT.

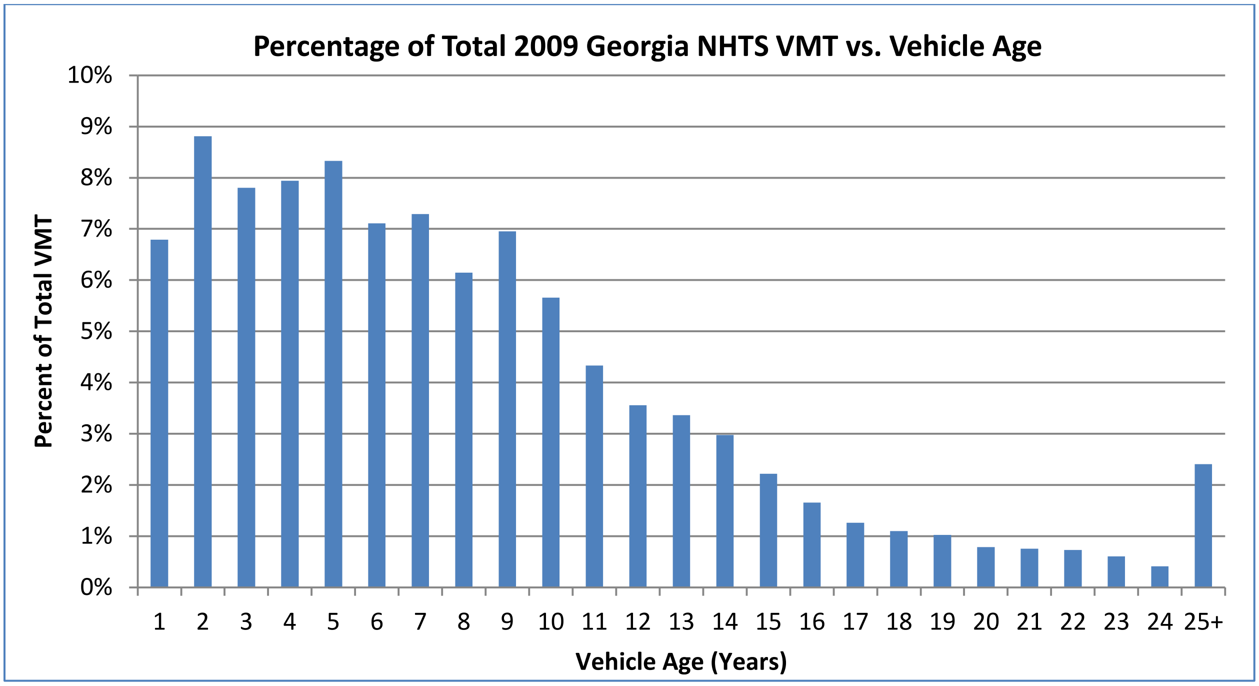

Figure 22: Percentage Distribution of Personal VMT by Vehicle Age

Figure 22 indicates that the majority of VMT is traveled by newer vehicles and that the annual number of miles traveled each year declines with increasing vehicle age. The right-most bar representing vehicles 25 years and older is significantly higher because it includes VMT for multiple model years. These percentages were then multiplied by the total personal VMT value of 87.92 billion miles calculated in Table 3 to obtain a VMT value driven by vehicles for each model year.

Using the same NHTS dataset, the average fuel economy of each vehicle model year was then calculated. This distribution is shown in Figure 23.

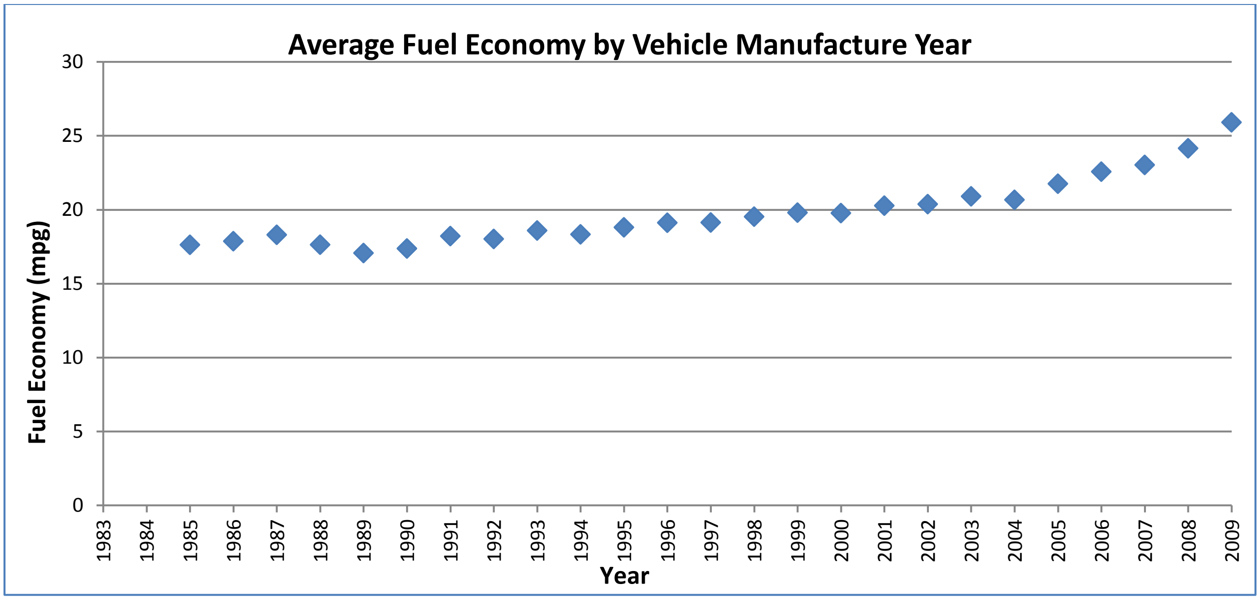

Figure 23: Average Fuel Economy Distribution by Vehicle Model Year

One can see from Figure 23 that the average fuel economy of each model year has increased slowly but steadily from an average of approximately 17 mpg in 1984 to approximately 26 mpg in 2009. It should be noted that this dataset includes personal vehicles of all types such as cars, light-duty trucks and SUVs. While some research efforts attempt to categorize fleet data by vehicle type, this model classifies vehicles by their age or model year. Increased stratification provided superior precision in determining an overall personal fleet fuel economy.

The above figures and tables detail how both average VMT and average fuel economy were calculated for each model year for personal vehicles. These two inputs can thus allow one to calculate fuel consumption per model year, which can then be summed to total fuel consumption. The fuel consumption calculation methodology is shown in Figure 24.

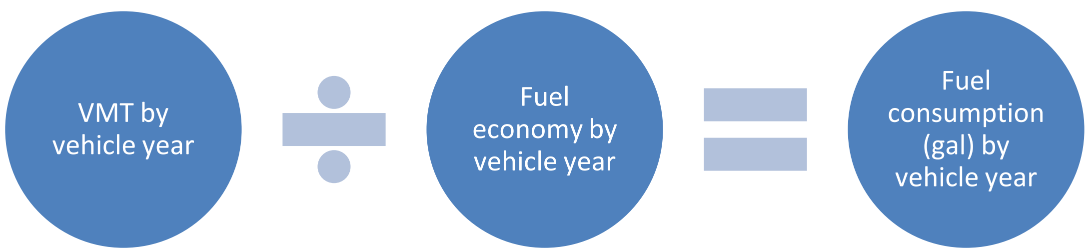

Figure 24: Fuel Consumption Calculation Methodology (by Vehicle Model Year)

Table 5 provides an abbreviated example of the process used to calculate fuel consumption by vehicle model year in Microsoft Excel. Only 4 of the 25 model year categories are shown for simplicity's sake; the full calculation process can be seen within the model itself.

Table 5: Example of Fuel Consumption Calculation Output

Vehicle Age (years)	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	24.2	23.0	22.6…
Fuel Consumption by Year (million gallons)	234	325	302	314 …

Once the fuel consumption for each model year had been calculated, the only step remaining in calculating motor fuel tax revenue from personal VMT was to apply the appropriate excise rate and sales tax percentage. Table 6 shows the application of these rates and the resulting revenue received from each model year.

Table 6: 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	$ 24,050,480	$ 22,349,912	$ 23,195,085…
Sales Tax Receipts ($)	$16,316,499	$22,694,033	$ 21,089,377	$ 21,886,882…
	Gas Price	Tax Per Gallon	Sales Tax Percent	
	$2.10	$0.075	3%	

The table 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, by using the tax rates to work backwards to the pre-tax price. To obtain the gas price in Georgia, the "historical charts" feature of the website was used to query the gas price in the state during GDOT's 2009 fiscal year, which spanned July 2008 to June 2009. 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 6. 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. Regardless of where fuel tax are paid, this process illustrates that fuel price is an important input in calculating motor fuels tax revenue due to the sales tax component of Georgia's revenue collection.

While the methodology for calculating both the VMT and fuel economy for personal vehicle is sound, some limitations exist. These include the aforementioned discrepancy of not accounting for out of state vehicle VMT within Georgia as well as potential sampling error within the 2009 NHTS's survey procedures. This sampling error could have affected values such as the percentage of VMT by vehicle model year and the model year fuel economy.

3.4 Freight Fleet Revenue Calculation & Methodology

3.4.1 2009 Georgia Freight Vehicle VMT Calculation

The process for modeling and calculating revenue from freight vehicles in Georgia in 2009 relied on the FHWA's Highway Performance Monitoring System (HPMS) data. This dataset tracks VMT throughout the nation using detectors on the road network and classifies it according to vehicle type and road functional class. Single-unit trucks and combination trucks were classified separately in this research due to their unique fuel economy characteristics and because there was distinct data available for each truck type in the HPMS database. Table 7 shows the VMT in 2009 traveled on each road type functional class and the percentage of trucks within the entire fleet mix. These two values are then multiplied to calculate the truck VMT per each road type functional class and then the total truck VMT.

Table 7: Truck VMT Calculation in Georgia

Functional Classification	Total VMT	Single Unit	Combination Truck (%)	Single Unit Truck VMT	Combination Truck VMT	Total Truck VMT (billions)
Interstate	31.79	3.00%	18.10%	0.95	5.75	6.71
Arterial	40.50	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 7 shows that the estimated 2009 truck VMT in Georgia was just less than 13 billion miles, which is significantly less than the estimated personal VMT of nearly 88 billion miles. The majority of freight miles are driven in combination trucks, most likely on long-haul interstate trips. Single-unit truck VMT is more likely to occur within urban areas and on arterial streets or local roads to make deliveries. Because truck VMT is estimated on data from the HPMS system and not by household, accuracy should be high and there should be no issue concerning whether vehicles are registered in Georgia or out of state, as all miles are gathered equally.

3.4.2 Freight Fuel Economy

Unlike with personal VMT, freight VMT and fuel economy were not stratified by vehicle model year. The logic behind this decision was that it is difficult to ascertain the age of vehicles driving specifically in Georgia due to the national characteristic of freight shipping and there was less information on heavy truck fuel economy by model year for those trucks driving in Georgia. Furthermore, according to the sources surveyed, average heavy truck fuel economy has varied so little in recent years that the impact of classifying freight vehicles by model year would have significantly less impact than it did when applying this same procedure to personal automobiles. However, even with this more simplified approach for freight vehicles, average fuel economy values still needed to be obtained. Fuel economies of 5.7 mpg for combination trucks and 9.0 mpg for single-unit trucks were obtained from a National Research Council report on freight vehicles (National Research Council, 2010). These values were representative of the entire fleet and not of a specific model year. These fuel economies, in conjunction with the aforementioned freight VMT values, were used to calculate total freight fuel consumption. These values will be presented later in this report.

3.4.3 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 (U.S. Energy Information Administration). From this database, the listed weekly diesel price in Georgia was averaged for each week in GDOT's 2009 fiscal year. The resulting average came out to be $2.96 (United States Energy & Information Administration , 2012). 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. The resulting pre-tax diesel price is $2.54.

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 (U.S. Census Bureau). Of all combination trucks, the survey found that 6.5% of trucks consumed gasoline and 93.3% consume diesel fuel (U.S. Census Bureau). 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 transit 2009 VMT in Georgia was tabulated using the 2009 National Transit Database (NTD). Total bus and/or paratransit gasoline or diesel VMT (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 NTD. Table 8 illustrates this tabulation.

Table 8: 2009 Georgia Transit VMT Tabulation (National Transit Database)

Transit Agency (Source 2009 National Transit Database)	VMT (thousands)
Hall Area Transit(HAT)	356.2
Albany Transit System(ATS)	657.8
Athens Transit System(ATS)	965.1
Augusta Richmond County Transit Department(APT)	756.2
Buckhead Community Improvement District(BCID)	201.5
Chatham Area Transit Authority(CAT)	3,262.5
City of Rome Transit Department(RTD)	593.8
Clayton County Board of Commissioners(CTRAN)	1,688.9
Cobb County Department of Transportation Authority(CCT)	4,764.0
Douglas County Rideshare(Rideshare)	1,075.2
Georgia Regional Transportation Authority(GRTA)	4,266.2
Gwinnett County Board of Commissioners(GCT)	3,608.5
Macon-Bibb County Transit Authority(MTA)	1,192.0
Marietta - VPSI, Inc.	4,656.3
Metra Transit System(Metra)	1,104.1
Metropolitan Atlanta Rapid Transit Authority(MARTA)	38,356.1
University of Georgia Transit System(UGA)	723.0
Total Georgia Transit VMT (thousands)	68,227.4

From Table 8 one can see that the total transit VMT is 68.2 million miles, which is insignificant compared to both personal and freight VMT, roughly 88 billion and 13 billion miles, respectively. Nevertheless, fuel consumption for transit vehicles was calculated 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 (National Research Council, 2010). Because the NTD did not always specify what vehicle type was used for a given entry, it was assumed that this 5.5 mpg is the average across large buses and smaller paratransit vehicles.

3.6 VMT Comparison

Model validation was done by comparing the estimated 2009 VMT and revenue with established values. Table 9 shows the calculated VMT for each category and the 2009 HPMS VMT value for the state of Georgia.

Table 9: Total Estimated VMT per category with comparison against HPMS Estimate

Travel Mode	VMT (billions)
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%

Before interpreting the values and comparison made in Table 9, several caveats should be considered. First is the limitation of the process in estimating personal VMT, as it does not account for VMT from non-Georgia households driven in Georgia and vice-a-versa. Second, the model does not account for VMT from company vehicles, agricultural vehicles traveling on roads, or private transit agencies' VMT. Finally, the HPMS value is also an estimate, albeit one regarded to be accurate; there is likely some error within this value as well. Discrepancies attributed to personal VMT likely represent the greatest error of any of the three categories (personal, freight, transit) in the validation process. However, because this model will be used in large part to compare future revenue against current revenue, any error in the model will be systemic and thus minimized.

3.7 Revenue Validation

The final comparison to be made with the 2009 model focuses on revenue. Establishing a sound foundation prior to projecting is crucial in creating a credible model. Table 10 depicts the modeled 2009 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 2.5% of the published revenue, which implies that the logic used in creating the model is acceptable for future revenue projections. The fact that the modeled VMT and revenue are less than the actual values for these variables is logical, as one would expect that less VMT would lead to less revenue. Despite this discrepancy, the model's logic in projecting forward is still sound, as these errors are systemic and will be carried forward throughout the model in the projection process. 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 revenue accounts for nearly one-third of total revenue. In the model, revenue from transit vehicles is less than 1% of the total revenue.

There are several reasons for the error discrepancy in addition to the VMT discrepancies mentioned earlier. 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 was that GDOT's 2009 fiscal year was exceptionally unique, as that time period saw both very high fuel prices (~$4.00/gallon) and relatively very low fuel prices (~$1.50/gallon). The extreme fluctuation in both fuel price and the economic turmoil makes compensating for the difference in fiscal and calendar year difficult. Second is that projected revenue can change dramatically after one even slightly adjusts single-unit and combination truck fuel economy. The magnitude of the impact is high for two reasons. First is that a single fuel economy value is being applied across a relatively high VMT value to obtain fuel consumption as compared to the stratified model-year approach employed in calculating fuel consumption with personal vehicles. Second is that the fuel economy of freight vehicles is low, and thus any adjustment has a greater relative percentage than the same magnitude of adjustment on a higher fuel economy value. In more direct terms, 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.

Table 10: 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 (billions of gallons)	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 (billions of gallons)	2.07
Excise Tax Revenue	$154,920,104
Sales Tax Revenue	$168,453,410
Total Freight Receipts	$323,373,513
FY 2009 Transit Receipts	
Total Transit Fuel Cons (billions of gallons)	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%

3.8 Model Evaluation & Validation Analysis

The -2.14% differences in the model estimate and HPMS estimate shown in Table 10 indicates 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 model 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 11 shows this process.

Table 11: 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, or a factor of 1.09. 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 12 presents multiple revenue values using the adjusted VMT values from Table 11 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 (Federal Highway Administration, Southworth & Gillett).

Table 12: 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	$ 997,487,594	3.91%
Model Revenue using Highway Statistics Fuel Economy: 7.4 mpg single-unit trucks; 6.0 mpg combination trucks	$991,175,785	3.25%
Model Revenue using Southworth & Gillett Fuel Economy: 12.6 mpg single-unit trucks; 5.1 mpg combination trucks	$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 12.

Chapter 4: Model Projections

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 year 2020 was chosen because of a greater availability of cited data with tighter parameters. The year 2030 was chosen 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 25 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.

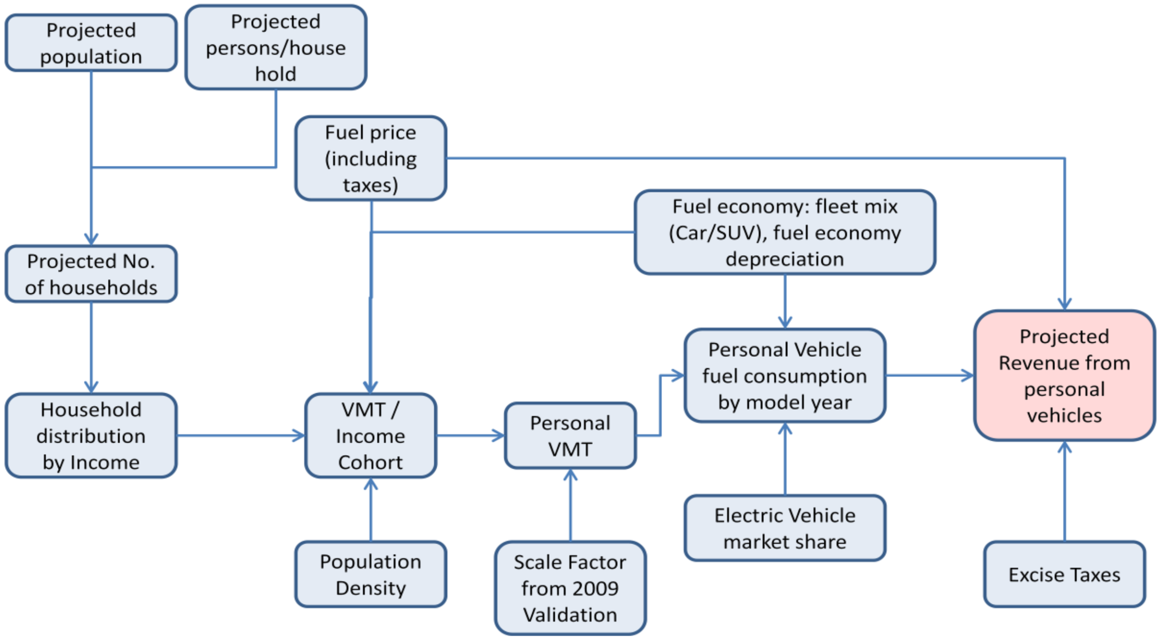

Figure 25: Personal VMT Projection Methodology

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 (Regional Economic Models Inc., 2010). 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 (Atlanta Regional Commission, 2011). 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 25 is household distribution by income cohort. The model incorporates data from the 2009 ACS to generate a distribution of households by income cohort (U.S. Census Bureau, 2011). 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 (Task, 2011). 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 13 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 distribution percentages.

Table 13: 2020 Household Distribution by Income with Multiple Scenarios

Income	**2009 Percentage Scenario**		**Alternative Scenario Percentages**	
Total households	2009 Percents	2009 Cohort	Alternative	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 25) is VMT per income cohort. The 2009 model calculates these values by averaging household VMT per cohort. Although not shown graphically in Figure 25, 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.

$$VMT_{Future} = VMT_{2009}\left(\frac{Fuel\ Price_{2009}}{Fuel\ Price_{Future}}\right)\left(\frac{Fuel\ Economy_{Future}}{Fuel\ Economy_{2009}}\right) * Population\ Density\ Factor$$

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 14 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 14: Fuel Economy by Income

Income Level ($)	Fuel Economy of vehicles with VMT greater than their given household's average VMT (cars with greatest usage in their respective households)
<10,000	19.98
10-15K	20.11
15-25K	20.47
25-35K	20.59
35-50K	21.11
50-75K	21.35
75-100K	21.40
100K+	21.39

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 15 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 15 and Commuting in America III (Transportation Research Board, 2006).

Table 15: Projected Average Model Year Purchase by Income Cohort

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 equation at the beginning of section 4.2.3, 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 16 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 16: Gasoline Price Entry Example

Gasoline Price before taxes	$3.90
State Excise Tax / gal	$0.075
Federal Excise Tax / gal	$0.184
State Sales Tax %	3%
Gasoline Price after taxes	$4.28

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 (Energy Information Administration, 2011). In nominal values, these prices are equivalent to $4.08 and $5.28 per gallon (Energy Information Administration, 2011). However, this report 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 (Deffeyes, 2008) (Steiner, 2009) (Gilbert & Perl, 2010).

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 (Litman, The Future Isn't What It Used to Be: Changing Trends and Their Implications for Transport Planning, 2011). 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 17 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 17: Population Density Inputs & Equations by Income Cohort

		2020	**2020**	**2030**	**2030**	
Income Level ($)	**Original Value**	**Percent Change (User**	**VMT Change Factor**	**Percent Change (User**	**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 25) have been satisfied, the model then uses the same categorical - proportional technique described in Section 3.3 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 at the end of Chapter 7.

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 (Environmental Protection Agency and National Highway Traffic Safety Administration, 2011). The model extends these projections to 2030 using best-fit regression equations. Table 18 illustrates these values and projections.

Table 18: Lower & Upper Bound Fuel Economy of Cars and Light Duty Trucks 2016-2025 with Regression Extension to 2030 (EPA and NHTSA)

CAFE Fuel Economy Targets				
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
2026	46.53	62.35	31.70	53.22
2027	48.13	64.51	33.52	56.10
2028	49.72	66.67	35.55	9.16
2029	51.32	68.83	37.80	62.42
2030	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 19 provides an example of the model user input.

Table 19: 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 19 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 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 (Gilbert & Perl, 2010).

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 (Vasudevan & Nambisan, 2011).

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 (Center for Automotive Research, 2011). 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 26 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)	38.96	37.61	36.42	35.20	33.37	32.16
Fuel Consumption by Year (million gallons)	182	248	231	247	278	250
Excise Tax Receipts ($)	$13,612,926.62	$18,603,347.64	$17,318,744.60	$18,531,179.81	$20,850,214.34	$18,759,392.81
Sales Tax Receipts ($)	$31,358,737.77	$42,854,671.62	$39,895,460.07	$42,688,425.80	$48,030,553.75	$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 26: Electric Vehicle 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 (Environmental Protection Agency and National Highway Traffic Safety Administration, 2011). 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 (Zhou, Vyas, & Santini, 2012). 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 (Keith, Sterman, & Struben, 2012). They have also developed a flow chart that helps to illustrate the hybrid vehicle adoption process. Figure 27 illustrates this process.

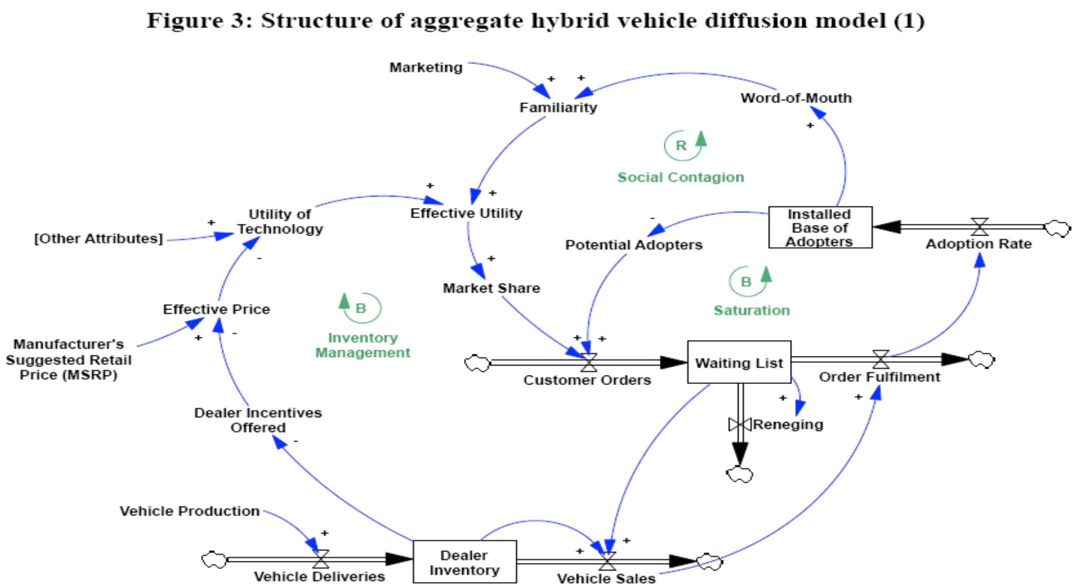

Figure 27: Hybrid/Alternative Vehicle Adoption Flow Chart (Keith, Sterman, & Struben, 2012)

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 (Saphores & Nixon, 2012).

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 25. 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 20 illustrates this method (in the table vehicle age increases from right to left but calendar year decreases).

Table 20: 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 20 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 28 has fewer inputs than the personal vehicle framework seen in Figure 25. The model uses the FHWA's 2009 HPMS data to project single-unit and combination truck VMT for the given year.

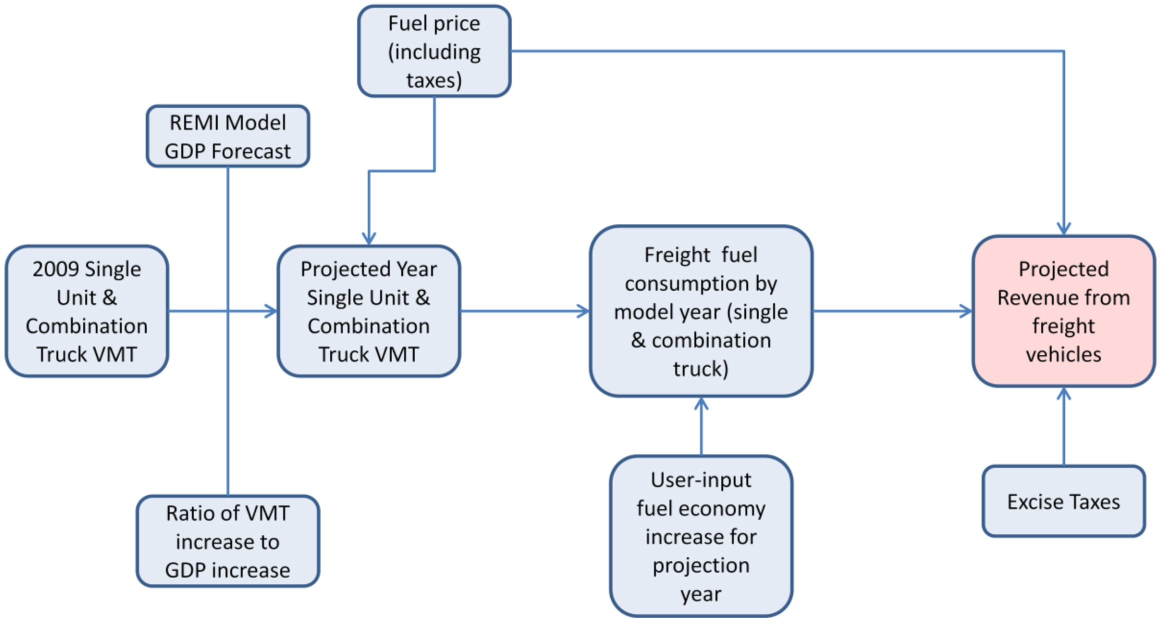

Figure 28: Freight Projection Methodology Flowchart

The figure 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 (U.S. Department of Energy, 2005). 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 (Regional Economic Models Inc., 2010). 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 21.

Table 21: Projected GDP Values 2009-2040 (REMI)

Year	2009	2010	2011	2012	2013	2014	2015	2016
GDP	230	238	252	268	285	303	323	345
Ratio of YearGDP to 2009	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	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	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	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 (Bureau of Transportation Statistics, 2011). 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 21 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 22). 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 (United States Energy & Information Administration , 2012). 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 (Litman, Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior, 2011). 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:

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

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 22 summarizes the data obtained from a department of energy web page displaying this distribution (U.S. Department of Energy, 2005).

Table 22: Freight VMT Distribution Percentage by Truck Model Year

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 23, 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 23: Alternative VMT Distribution (Higher Fuel Prices)

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 22 or Table 23 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 24 shows an example of this multiplication for four of the 17 years that the truck VMT is distributed.

Table 24: 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…

4.3.4 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 (National Research Council, 2010) (Federal Highway Administration, 2012) (Southworth & Gillett, 2011). Table 25 shows an example of the fuel economy for each model year based on a projected 25% freight fuel economy increase in 2030.

Table 25: 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

The table 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.

4.3.5 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 (U.S. Census Bureau, 2005). Excise and sales taxes are then calculated for each vehicle's model year with fuel price and fuel consumption data. Table 26 provides sample freight fuel consumption and revenue data.

Table 26: 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.

4.3.6 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 27 provides an example of this calculation.

Table 27: 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 27 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 Use Instruction

The Revenue Toolbox model is meant to be user-friendly and encourage the user to experiment with different inputs to assess how different input scenarios impact revenue. Although this report provides background into the logic and reasoning behind the model, it is intended that one can use the model independently from this document once one has familiarized themselves with the background methodology. The first tab of the Revenue Toolbox, labeled “User Instructions,” provides direction as how to proceed through the model and an explanation of each of the tabs. Furthermore, each tab has additional explanation via either textboxes at the top of the tab or comments boxes for user-inputs. *Because of these comment boxes, it is recommended that the user turn on the “show comments” feature listed in the “Review” tab of Microsoft Excel.*

The Toolbox includes tabs that show the 2009 estimate and validation, background calculations for population density, fuel economy, GDP, and the 2020 and 2030 projection tabs. The model user is prompted to enter all inputs in the “UserInputs” and “FutureFuelEcon” tabs. The revenue is output just below the inputs in the “UserInputs” tab. In the model, orange cells denote input cells. These orange input cells are held in orange input tabs to inform model users where they should click to input data. The revenue is output in total dollars and in per-capita and per-mile figures for both 2020 and 2030. Income metrics are output in the 2009 assumption and alternative assumptions for each year. All dollar inputs and outputs are in 2009 dollars.

Although the revenue is output in the “UserInputs” cell for convenience, the “2020” and “2030” tabs perform the actual model calculations. Within the 2020 and 2030 tabs, flowchart arrows and comments guide the user through the model structure. This flowchart mimics the flowcharts seen in Chapter 4 that describe the personal and freight projection frameworks. These flowcharts illustrate the calculate process and denote which datasets were used. The “2020” and “2030” tabs pull data from the “UserInputs” tab as well as from the other non-highlighted tabs that store calculation information. Although users can examine the “2020” and “2030” tabs to better understand the model’s inner-workings, this is not required. Users may simply only work from the “UserInputs” and “FutureFuelEcon” tabs to gain revenue output. Table 28 on the following page illustrates the user input interface.

Table 28: User Input Interface

Projection Year	2020	2030
Gasoline Price before taxes	$3.02	$4.02
State Excise Tax / gal	$0.075	$0.075
Federal Excise Tax / gal	$0.184	$0.184
State Sales Tax %	3%	3%
Gasoline Price after taxes	$3.38	$4.41
Diesel Price before taxes	$3.18	$3.18
State Diesel Excise Tax/ gal	$0.075	$0.075
Federal Diesel Excise Tax/ gal	$0.244	$0.244
Diesel Sales Tax %	3%	3%
Diesel Price after taxes	$3.60	$3.60
Ratio of Freight VMT to GDP change	0.10	0.10
Increase in Freight Fuel Economy from 2009 to 2020 (%)	17.8	17.8
Factor to Increase Transit VMT vs. 2009 Transit VMT	5	5
Increase in Transit Fuel Economy from 2009 to 2020 (%)	17.8	17.8
Fuel Efficiency Depreciation Rate (Compounded Annually and Multiplied by Original Rate)	0.985	0.985
Electric vehicle market share as a percentage of 2020 vehicle sales	5	20
Persons per Household	2.72	2.67

Alternative Income Percentage Distribution (Must Sum to 100)	2020	2030
Less than $10,000	8.9	8.9
$10,000 to $14,999	6.3	6.3
$15,000 to $24,999	11.7	11.7
$25,000 to $34,999	11.0	11.0
$35,000 to $49,999	14.6	14.6
$50,000 to $74,999	18.2	18.2
$75,000 to $99,999	11.6	11.6
$100,000+	17.7	17.7

Population Density Change by Income Cohort (Positive Values Result in Less VMT, Negative Values Result in More VMT)	2020	2030
Less than $10,000		
$10,000 to $14,999		
$15,000 to $24,999		
$25,000 to $34,999		
$35,000 to $49,999		
$50,000 to $74,999		
$75,000 to $99,999		
$100,000+		

Table 29 illustrates the revenue output interface.

Table 29: Sample Revenue Output Interface

Revenue Outputs			
Metric / Year	2020	2030	2009
Projected Revenue Using 2009 Income & VMT Distribution	$1,155,272,679	$1,159,156,309	$960,000,000.00
Revenue Per Mile (¢/mi)	0.82	0.72	0.88
Revenue Per Capita ($/person)	$93.74	$83.37	$98.97
Projected Revenue Using Alternate Distribution	$1,168,057,936	$1,157,092,498	N/A
Revenue Per Mile (¢/mi)	0.83	0.72	
Revenue Per Capita ($/person)	$94.78	$83.23	

Although the model is intended to be used as an input-output model with infinite input scenarios, Chapter 6 presents some default conservative and aggressive scenario inputs with corresponding revenue output for 2020 and 2030.

Chapter 6: Sample Scenario Results

The sample inputs below are meant to give the model user an idea of what outputs are to be expected and how different input scenarios can affect model revenue. This document includes four scenarios – conservative and aggressive scenarios for both 2020 and 2030. The conservative scenarios use values found in literature and “business as usual” projections through 2030. These inputs are presumed to result in relatively higher revenue outputs than the aggressive scenarios, which assume greater technological advancement in terms of fuel economy and electric vehicle technology, as well as more significant land use and economic changes. These inputs and revenues are not defaults and are only meant to provide a range of potential revenue output values.

6.1 2020 and 2030 Conservative Scenarios

The values presented in Table 30 on the following page illustrate the conservative scenario inputs for the years 2020 and 2030. As can be seen from the table, the projection assumes only moderate increases in gasoline and diesel price for each year. The scenario assumes a 17.8% increase in freight and transit fuel economy by 2020 and a 30% increase by 2030. These increases are based on annual growth rates. The 2020 scenario assumes a 5% market penetration by VMT of electric vehicles and the 2030 scenario assumes a 10% market penetration by VMT. Both scenarios assume constant household income distribution from 2009. The 2020 scenario incorporates no change in population density while the 2030 scenario presumes a 10% increase in population density for poorer cohorts and a 5% increase for wealthier cohorts. Fuel Economy Inputs are not shown but the 2020 scenario assumes half of all vehicles purchased will be automobiles and half will be SUVs. The 2030 scenario assumes that the fleet mix will start half car half SUV but will eventually transition to a 60/40 car/SUV fleet mix by 2030. All other input values are shown in the table.

Table 30: 2020 and 2030 Conservative Inputs

Projection Year	2020	2030
Gasoline Price before taxes	$3.02	$3.28
State Excise Tax / gal	$0.075	$0.075
Federal Excise Tax / gal	$0.184	$0.184
State Sales Tax %	3%	3%
Gasoline Price after taxes	$3.38	$3.65
Diesel Price before taxes	$3.18	$3.42
State Diesel Excise Tax/ gal	$0.075	$0.075
Federal Diesel Excise Tax/ gal	$0.244	$0.244
Diesel Sales Tax %	3%	3%
Diesel Price after taxes	$3.60	$3.85
Ratio of Freight VMT to GDP change	0.10	0.10
Increase in Freight Fuel Economy from 2009 to 2020 (%)	17.8	30
Factor to Increase Transit VMT vs. 2009 Transit VMT	5	10
Increase in Transit Fuel Economy from 2009 to 2020 (%)	17.8	30
Fuel Efficiency Depreciation Rate (Compounded Annually and Multiplied by Original Rate)	0.985	0.985
Electric vehicle market share as a percentage of 2020 vehicle sales	5	10
Persons per Household	2.72	2.67

Alternative Income Percentage Distribution (Must Sum to 100)	2020	2030
Less than $10,000	8.9	8.9
$10,000 to $14,999	6.3	6.3
$15,000 to $24,999	11.7	11.7
$25,000 to $34,999	11.0	11.0
$35,000 to $49,999	14.6	14.6
$50,000 to $74,999	18.2	18.2
$75,000 to $99,999	11.6	11.6
$100,000+	17.7	17.7

Population Density Change by Income Cohort (Positive Values Result in Less VMT, Negative Values Result in More VMT)	2020	2030
Less than $10,000	0	10
$10,000 to $14,999	0	10
$15,000 to $24,999	0	10
$25,000 to $34,999	0	10
$35,000 to $49,999	0	5
$50,000 to $74,999	0	5
$75,000 to $99,999	0	5
$100,000+	0	5

Table 31 shows the revenue output for both the 2020 and 2030 conservative scenarios. Although these scenarios assume a constant income distribution from 2009, the output of both the 2009 and alternative income distributions are shown.

Table 31: Revenue Output for 2020 and 2030 Conservative Scenarios

Revenue Outputs			
Metric / Year	2020	2030	2009
Projected Revenue Using 2009 Income & VMT Distributions	$1,155,272,679	$1,101,237,892	$960,000,000
Revenue Per Mile (¢/mi)	0.82	0.68	0.88
Revenue Per Capita ($/person)	$93.74	$79.21	$98.97
Projected Revenue Using Alternative Income & VMT Distribution	$1,168,057,936	$1,097,420,057	N/A
Revenue Per Mile (¢/mi)	0.83	0.68	
Revenue Per Capita ($/person)	$94.78	$78.93	

The table shows that 2020 revenue will be significantly higher than the actual revenue observed in 2009; however, it also indicates that real revenue will decline between 2020 and 2030. This decline is likely due to the increase in percentage of electric vehicles and the increase in passenger and freight fuel economies. In addition to the significant decline in absolute revenue between 2020 and 2030, there was also a significant decline in per-mile and per-capita revenue between 2020 and 2030. The 2020 values were much closer to the revenue values seen in 2009 than those seen in 2030, indicating that a bigger change in revenue is likely to occur between 2020 and 2030 than between and 2009 and 2020, at least with these inputs.

6.2 2020 and 2030 Aggressive Scenarios

These scenarios assume higher fuel prices, greater fuel economy improvement, a higher percentage of electric vehicles, and increase population density and changes in income distribution as compared to the more conservative scenarios. The fuel prices were adjusted by increasing the Energy Information Administration’s 2030 projections upward by 15%. The income and population density adjustments were made based on ideas and concepts gleaned from the literature review. Freight and transit fuel economy improvements were again based off of annual growth rates, although these growth rates were assumed to be higher than those in the conservative scenario. Both years’ scenarios also assume that light trucks’ fleet mix share will continuously decrease by 1% each year starting in 2015. All inputs except for the fuel economy fleet share are shown in Table 32 on the following page.

Table 32: 2020 and 2030 Aggressive Scenario Inputs

Projection Year	2020	2030
Gasoline Price before taxes	$3.51	$3.81
State Excise Tax / gal	$0.075	$0.075
Federal Excise Tax / gal	$0.184	$0.184
State Sales Tax %	3%	3%
Gasoline Price after taxes	$3.88	$4.19
Diesel Price before taxes	$3.64	$3.94
State Diesel Excise Tax/ gal	$0.075	$0.075
Federal Diesel Excise Tax/ gal	$0.244	$0.244
Diesel Sales Tax %	3%	3%
Diesel Price after taxes	$4.08	$4.39
Ratio of Freight VMT to GDP change	0.10	0.10
Increase in Freight Fuel Economy from 2009 to 2020 (%)	21	37
Factor to Increase Transit VMT vs. 2009 Transit VMT	5	15
Increase in Transit Fuel Economy from 2009 to 2020 (%)	21	37
Fuel Efficiency Depreciation Rate (Compounded Annually and Multiplied by Original Rate)	0.985	0.985
Electric vehicle market share as a percentage of 2020 vehicle sales	10	30
Persons per Household	2.75	2.75

Alternative Income Percentage Distribution (Must Sum to 100)	2020	2030
Less than $10,000	9.0	9.0
$10,000 to $14,999	7.0	7.0
$15,000 to $24,999	12.5	12.5
$25,000 to $34,999	11.5	11.5
$35,000 to $49,999	13.5	13.5
$50,000 to $74,999	17.0	17.0
$75,000 to $99,999	11.5	11.5
$100,000+	18.0	18.0

Population Density Change by Income Cohort (Positive Values Result in Less VMT, Negative Values Result in More VMT)	2020	2030
Less than $10,000	5	20
$10,000 to $14,999	5	20
$15,000 to $24,999	5	20
$25,000 to $34,999	5	20
$35,000 to $49,999	5	15
$50,000 to $74,999	5	15
$75,000 to $99,999	5	12
$100,000+	5	12

Table 33 shows the revenue outputs for each year's aggressive scenario. Due to the higher fuel prices and alternative income distributions used, only the alternative income and VMT distribution scenario outputs are shown in this case

Table 33: 2020 and 2030 Aggressive Scenario Revenue Output

Revenue Outputs			
Metric / Year	2020	2030	2009
Projected Revenue Using Alternative Income & VMT Distribution	$1,138,621,235	$1,076,323,058	N/A
Revenue Per Mile (¢/mi)	0.82	0.68	
Revenue Per Capita ($/person)	$92.39	$77.42	

The table shows that the aggressive scenario's revenue output is less than the conservative scenario's output for both years. This is likely due to lower fuel consumption values via higher fuel economies and higher electric vehicle market penetration values. These decreases in fuel consumption were somewhat offset by higher sales tax revenue from higher fuel prices, but not enough to make up for the lack of revenue created by lower fuel consumption. As was also seen in Table 31 in the conservative scenario, the aggressive scenario also projects significantly higher revenue in 2020 than GDOT actually received in 2009 actual revenue. However, the aggressive scenario also projects a decline in real revenue between 2020 and 2030. Table 33 also indicates that the per-capita and per-mile revenue values will also significantly decline between 2020 and 2030.

These scenarios are intended to provide a range of how the factors affecting fuel tax revenue could vary and how this range affects revenue output. Despite the differences between the conservative and aggressive scenarios, both scenarios indicate the potential for significant decreases in revenue between 2020 and 2030. Much of this decline is driven by increase in fuel economy, especially in the freight sector, and the market penetration of electric vehicles that do not consume gasoline. Chapter 7 further discusses the impact of each of these factors and provides overall concluding remarks.

Chapter 7: Conclusions

From GDOT's perspective, perhaps the most important conclusion that can be drawn from using the Revenue Toolbox is that significant declines in motor fuels tax revenue are possible within the next 10 to 20 years. While some of the inputs used were more aggressive than others, more aggressive scenarios should at least be considered and visualized. Although there are numerous inputs to the model, it was found that some inputs have a greater impact than others – especially in the 2030 projections.

7.1 Variables with More Impact

Some of the most important variables in the model are those that impact how many persons and households will be in Georgia in 2020 and 2030. Changing the number of people who are projected to live in the state or how densely they live alters the number of households generating travel. Although credible sources from the Atlanta Regional Commission were used in projecting these variables, it is difficult to know how demographics will change over a 10 – 20 year period.

Fuel economy improvement also has a significant impact on future revenue. The model allows users to input transit and freight fuel economy improvements in the form of a percentage increase over 2009. Even a small difference in percentage can make a significant difference in predicted revenue – especially in 2030. In conjunction with fuel economy, projected electric vehicle market share also has a very significant impact on revenue, again with a greater impact seen in 2030. As electric vehicle market penetration increases above 20%, a large number of miles are not being fueled by fuel and thus do not contribute to fuels tax revenue.

The ratio of freight VMT to GDP growth is also a significant variable, as even small growth in freight VMT can result in relatively large increases in motor fuels tax revenue. The model recommends a range of between 0.08 and 0.12 for this input, and thus there is only a small range of potential values to input; however, increasing the ratio from 0.09 to 0.11 can affect revenue substantially. As was explained earlier in the document, this input relates shipping activity to economic growth. In this model, economic growth is fixed as predicted by the REMI model.

Finally, the excise tax rate and sales tax percentage are the most significant variables and are the variables that GDOT likely has the most influence over. Increasing the excise or sales tax rates can recover the revenue lost to increased fuel economy or electric vehicles. Each of the scenarios shown in the previous section assumed constant excise and sales tax rates.

7.2 Variables with Less Impact

Variables with less impact include: household distribution among income cohorts, changes in population density, moderate changes in fleet mix, and all transit related inputs. It should be reinforced that these variables do impact fuel tax revenue and can significantly impact revenue if changed greatly from their 2009 values. For example, a 10% change in population density does relatively little, but a 50% change does result in significant changes. However, part of the reason these variables are deemed less important in terms of impact on model results is because the surveyed literature states that there is a lower likelihood for significant changes in these areas.

7.3 Concluding Remarks

Predicting motor fuel tax revenue one to two decades into the future involves numerous assumptions of future variable trends and how these variables interact in the future. Despite the limitations of these assumptions, this model not only incorporates many of the variables seen in Chapter 2's literature, but also provides the model user the ability to modify these variables to observe the impact of variable changes on travel behavior and ultimately, motor fuel tax revenue.

Understanding how different demographic, economic, environmental and governmental factors will affect future fuel tax revenue is important for many reasons. Changes in revenue not only affect Georgia's capacity to pay for transportation infrastructure, they could also affect the revenue mechanisms themselves. If fuel tax revenue declines significantly, a priori knowledge of such a decline will provide policy makers the ability to potentially increase fuel tax rates or devise a new revenue collection methodology to ensure steady financial capacity to construct and maintain Georgia's infrastructure. Not only will Georgia need to continue to pay for the maintenance of its road network, but it may also need to increase funding to other modes such as bike/ped, transit, and innovative transportation technologies to ensure safe mobility for its residents.

This model's structure and methodology is designed to stay relevant for many years. Because it is transparent and incorporates a multitude of user inputs, it can be saved and updated in future years as demographic, technological, environmental and governmental trends are established. Assuming the method for collecting transportation revenue remains constant, its values can be updated once more accurate projections have been established. These updates could then be used to predict revenue for years beyond 2030.

As Georgia's population and road congestion increases, an even greater strain will be placed on GDOT's transportation budget. Increasing freight traffic coupled with potentially more extreme weather events could accelerate the speed at Georgia's transportation infrastructure deteriorates. Innovative design and construction techniques will need to be devised to combat this acceleration, and funding will be needed to pay for these innovations. Understanding how much funding is and will be available under the current revenue collection system is an important aspect of assessing whether GDOT can continue to operate in its current capacity. This model is designed to provide this funding information under a myriad of future scenarios in order to aid GDOT planners in making these assessments.

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