Analyzing the Feasibility of a Highway User Fee for the State of Virginia

Prepared by:
Ian Millikan, Ray Kolley, Gerald Fleenor, Gabriel Ortiz, Bryan Vaughan, Scarlet Neece, Timothy Fitzgerald, Brian Truelove, Michael Black, and under the advisement of Dr. Frederick Ducca, Professor, TPOL Program

George Mason University
School of Public Policy
Transportation Policy Operations and Logistics
Fall Practicum 2008
## Contents

Acknowledgements ..................................................................................................................................... 4  
Disclaimer ................................................................................................................................................... 4  
Forward ....................................................................................................................................................... 4  
Problem Statement/Study Mandate ........................................................................................................... 4  
Executive Summary .................................................................................................................................... 5  
  Background .............................................................................................................................................. 5  
  Lessons Learned from Previous and On-going Studies .......................................................................... 6  
  Technical Feasibility.................................................................................................................................7  
  Policy Issues to Overcome ....................................................................................................................... 8  
  Pilot Study Logistics ................................................................................................................................ 9  
  Conclusion ..............................................................................................................................................10  
Introduction ............................................................................................................................................... 11  
  The Current Condition ........................................................................................................................... 11  
  Scope of the Report ................................................................................................................................ 11  
  Study Approach ...................................................................................................................................... 11  
Background ................................................................................................................................................12  
  Virginia’s Current Revenue Sources ......................................................................................................13  
    States Motor Fuel Tax .......................................................................................................................... 14  
    Motor Vehicle Sales and Use Tax ......................................................................................................... 14  
    Vehicle License Fees ........................................................................................................................... 14  
    Retail Sales and Use Tax ....................................................................................................................... 14  
    International Registration Plan Fee ...................................................................................................... 15  
    Federal Revenue .................................................................................................................................... 15  
    Transfer of Revenues ............................................................................................................................ 15  
    Toll Facilities ......................................................................................................................................... 15  
  Sources of Revenue for the HMOF and TTF-C ............................................................................................16  
  Alternative Revenue Sources .................................................................................................................. 17  
A Highway User Fee based on Vehicle Miles Traveled ......................................................................................17
Analyzing the Feasibility of a Highway User Fee for the State of Virginia

Risks and Benefits of a HUF .................................................................................................................. 17
HUF Enhancements ............................................................................................................................... 18

Previous and Ongoing Studies – Oregon Pilot Study ......................................................................... 18
Minnesota Study .................................................................................................................................... 21
Mileage-Based Road User Charge Study .............................................................................................. 22

Feasibility Study of Road Pricing in the UK ....................................................................................... 24

A HUF in Virginia .................................................................................................................................. 26

Technical Feasibility of a HUF ............................................................................................................. 26
Global Positioning System (GPS) ......................................................................................................... 27
Smart Card ............................................................................................................................................ 30

Odometer Based ................................................................................................................................... 33

Policy Issues ........................................................................................................................................ 35

Equity .................................................................................................................................................... 35
Income Level ........................................................................................................................................ 36
Geographic Location ............................................................................................................................ 36
Vehicle Type ........................................................................................................................................ 37
Privacy ................................................................................................................................................... 40

Addressing GPS privacy concerns ...................................................................................................... 40
Addressing Smart Card privacy concerns ............................................................................................ 40
Addressing Odometer-Based privacy concerns .................................................................................. 41

Mitigating Issues and Educating the Public ....................................................................................... 41

Possible Pilot Programs for Virginia .................................................................................................. 42
Conclusion .......................................................................................................................................... 45

References .......................................................................................................................................... 47
Acknowledgements

We would like to thank the following for helping to make this report possible:

**Dr. Jonathan Gifford** - Director of the Transportation Policy, Operations and Logistics Program at George Mason University and the visionary that suggested the topic for this report.

**Dr. Frederick Ducca** – one of the head transportation modelers at the Federal Highway Administration and the professor/mentor for the production of this report. His experience laden leadership helped direct the focus of the report onto the important factors that are facing the modern transportation industry.

**Dr. Anthony Rufolo** – Professor of Urban Studies and Planning at Portland State University and an instrumental part of the Oregon Pilot Program. His wisdom and insight into the logistics of operating a highway user fee program were shared while he was on sabbatical and working in Washington D.C. for the Department of Transportation.

Disclaimer

Any views and opinions expressed in this report are strictly those of authors and are not meant to reflect those of either George Mason University or The Virginia Department of Transportation.

Forward

This report serves as the capstone project for George Mason University’s Master’s Degree in Transportation Policy, Operations, and Logistics. The purpose of the capstone project is to allow students the opportunity to solve a “real world” problem using the knowledge and experience garnered from previous courses. George Mason University has teamed up with the Virginia Department of Transportation for this project to research the feasibility of implementing a Highway User Fee (HUF) based on vehicle miles traveled in Virginia.

Nine students in the Transportation Policy, Operation and Logistics Master’s Program at George Mason University have been tasked with the responsibility of researching and compiling this report. Their diverse undergraduate backgrounds and experience in engineering and transportation management have helped to make this study possible.

Problem Statement/Study Mandate

As Virginia struggles to maintain more and more miles of infrastructure, financing from its primary funding source for transportation, the fuel tax, is starting to decline. This decline is caused by a decrease in gasoline sales due to economic issues and the rising popularity of fuel efficient and alternatively fueled vehicles. This report will analyze whether it will be technically, economically, and politically feasible for the state of Virginia to introduce a HUF to supplement or replace the lagging fuel tax.
Executive Summary

This report is the main objective of the capstone practicum course for George Mason University Master’s Program in Transportation Policy, Operations and Logistics (TPOL). Nine students were given the assignment of coming up with options for a roadway user fee that would be based on the number of vehicle miles traveled (VMT) by Virginia drivers. Current funding sources for the state’s future and existing transportation projects are not delivering enough revenue for a varying degree of reasons; subsequently, interest has grown in finding a source of finance that is tied to the direct usage of the roadway system.

Virginia is a very unique state with its own set of issues, problems, and attributes. By analyzing other similar studies conducted in Oregon, Iowa, and across the world as guides, students were able to compile information and come up with technical solutions that could work in Virginia. Dr. Frederick Ducca, who served as the students mentor, was essential in keeping the students focused and organized. His vast experience in the arena of transportation research and project management was invaluable in guiding the students throughout the semester. Additionally, the students themselves served as valuable resources for one another. The TPOL program has a distant learning component to it that brings together students from four locations across Virginia: Arlington, Richmond, Bristol and Staunton. This allowed the students to share their diverse professional backgrounds which aided the study since the project traversed across several different industries and disciplines as well. The “client” for this research project is the Multi-Modal Transportation Planning Office of the Commonwealth of Virginia.

Background

It goes without saying that the construction and continual maintenance of Virginia’s roads, bridges, tunnels and other infrastructure are of paramount importance to the economic and social vitality of the state. Not only is Virginia’s transportation system very important, it is also very big; in fact, Virginia has the third-largest state-maintained highway system in the country, only trailing Texas and North Carolina. Over the last several years an alarming trend has been taking place in the Commonwealth that threatens the future of Virginia’s infrastructure. Economic issues are causing the state’s main revenue source for transportation funding, the gas tax, to lose its buying power. If left unadjusted, Virginia is at risk of losing its ability to generate enough funds to pay for the maintenance and construction required to upkeep its massive transportation network.

The fuel tax has been declining in recent years for a variety of reasons. Chief among them is the gas tax’s inability to keep pace with inflation. Although the gas tax is expected to net over $800 million between years 2008-2009, this represents the lowest amount that will be collected in nearly two decades after the figure is adjusted for inflation. Additionally, the gas tax does not have a mechanism to accurately reflect road wear and tear and it is extremely susceptible to technology that improves automobile fuel efficiency.

According to Virginia’s 2006 Transportation Performance Report, over 10% of interstate highway pavement, over 15% of pavement on primary roads (main roads that connect populated areas), and almost 50% of secondary roads (roads that connect primary roads) are considered deficient. To compound the problem, the statistics are worse for Virginia’s bridges. Virtually half of the state’s 12,000 publicly maintained bridges are considered deficient or structurally obsolete, and one-third of the state’s bridges are more than fifty years old. The revenues generated by the fuel tax are not going to be enough to solve these problems alone; truth be told, the declining purchasing power of the fuel tax is one of the main reasons Virginia’s infrastructure is in its current condition. The Virginia Department of Transportation (VDOT) projects a $2 to $2.5 billion shortfall in revenue between 2009 and 2014. An alternative that can make up for the
shortcomings of the gas tax will be desperately needed as Virginia’s roads, bridges and tunnels get older and more deficient.

One option for Virginia to supplement or replace the fuel tax would be to charge a highway user fee (HUF) to drivers that correlated with the number of VMT. The HUF would be different than the gas tax in many ways. First, it would almost be impervious to any foreseen advancements in fuel economy technology. Since fuel efficient vehicles like electric/gas and plug in hybrids (automobiles that can be charged in one’s home), as well as alternative fuel vehicles that use hydrogen and ethanol instead of gas, use less fuel per mile, drivers of these vehicles are essentially paying less taxes and receiving the same transportation benefits. At the same time, the state of Virginia receives less revenue from the fuel tax because fuel efficient vehicles allow drivers to travel more miles on less fuel. Implementing a HUF would also give Virginia the option to use new technology to of take advantage additional applications. A HUF based on Global Positioning Systems (GPS) would allow Virginia to vary charges placed on drivers depending on the time and location they chose to travel. Virginia could use this information to combat congestion and vehicle pollution while it raises revenue for transportation construction and maintenance. Additional, the charge for a HUF would be similar to the way people are currently charged for utilities, so charging road users in the same manner should be an easy concept for the traveling public to comprehend.

**Lessons Learned from Previous and On-going Studies**

Several previous and ongoing studies were analyzed to determine feasible options for a HUF based on the amount of miles traveled by road users. One of the most prominent and expansive studies was conducted by the state of Oregon. In 2001, Oregon created a task force to research the possibility of a road user fee because the state legislature was worried that fuel efficient technology would deplete transportation revenue. The Oregon Department of Transportation ultimately conducted a small scale experiment/pilot study to see how effective and realistic a fee like this would be. One of the main goals of the study was to see if it was feasible to create a fee for service that would directly charge drivers for the amount of roads they use. After three years of preliminary research, it was decided that the pilot study would focus on odometer and GPS technologies. The study concluded that:

- The concept was viable.
  - At the conclusion of the pilot program, 91% of participants said that they would agree to continue paying the mileage fee in lieu of the gas tax if the program were extended statewide

- Paying at the pump works.
  - The pilot program showed that the mileage fee could be paid at the pump, with minimal difference in process or administration for the motorist compared to how the fuel tax is currently collected.

- The mileage fee can be phased in.
  - The study showed that the mileage fee could be phased in gradually alongside the gas tax.

In addition, other important findings of the project were that privacy could be protected, there would be minimal burden on businesses, evasion was unlikely, and there would be a low cost to implement and administer the HUF for the government.

The state of Minnesota, in conjunction with the Federal Government and consultants from Cambridge Systematics, also conducted a study that investigated the possibility of charging drivers for their road usage titled Pay-As-You-Drive (PAYD). The Minnesota Department of Transportation carried out a PAYD demonstration which was intended to test the idea that if people are given frequent price signals regarding the costs of their automobile use, they may reduce the number of miles they travel, and, as a result, help to alleviate congestion and air quality problems. This was accomplished by simulating the conversion of vehicles fixed costs, such as leasing or insurance, to variable costs and providing
frequent price signals. The focus of this study was market research into customer acceptance of mileage based fees. A survey of Twin City’s area residents gauged interest in PAYD concepts for leasing and insurance. Although 25% of respondents indicated some interest in the concept of PAYD, interest dropped to 18% when participants were given specific choices. Reasons cited for the lack of interest were the uncertainty of monthly costs, privacy concerns, and a general dislike for leases. It is important to point out, however, that respondents were most attracted to the concept of paying based on the amount of miles they actually drove. The findings of the Minnesota study indicated that PAYD products do appeal to a small, but not insignificant portion, of the population, and that PAYD programs will be most effective when they are designed to focus on specific sub-samples of the overall population.

Another HUF study was conducted by the University of Iowa’s School of Public Policy. This study is unique in that it involved 15 states from as far away as California and as close as North Carolina. The primary goals of this study were:

1. To make sure that the system is reliable, secure, flexible, user-friendly and cost-effective.
2. To find out why vehicle operators accept or reject the system and to determine what they like and what they don’t like.

Study participants had an on-board computer temporarily installed in their vehicles. The installation was seamless and designed to cause no major alterations or damage to the vehicle. The computer collected miles traveled by the driver and recorded charges participants would have to pay for their road usage. This data was uploaded to a data/collections processing center and mock bills were sent to participants. Although the bills did not have to be paid, they gave participants a feeling for how much their driving would cost them if a HUF was implemented. The report concluded that a HUF offered the following advantages: rates can be set for different types of vehicles, the system can be used to help reduce problems like traffic congestion, and the system features a low-cost and familiar approach to fee collection.

Technical Feasibility

With respect to Virginia and the possibility of a HUF, it was important to research and analyze the different types of technologies that would make such a fee actually feasible. The studies previously mentioned all used different types of technology, and while all would work with Virginia, it was difficult to assess which one would work best. Consequently, different types of technologies were researched and studied. While the technologies discussed in the previous and ongoing studies had different attributes, one commonality was that each used an on-board-computer to track vehicle miles traveled. The technical options that are currently available to Virginia for implementing a HUF are GPS, Smart Card, and an odometer. Virginia could choose to use any combination of these technologies for various reasons.

GPS technology would greatly enhance either a Smart Card or Odometer technology option. Depending on the required accuracy of the data, however, a GPS unit can be very expensive for the consumer. GPS is beneficial because it can track the mileage as well as the time and location of trips so it can differentiate between geographic zones and boundaries, such as urban areas or state lines. This information would then be transferred to a collection center that would process it and calculate an applicable charge for the driver based on how far, and, if desired, when and where they drove. Although GPS technology would add an additionally administrative burden on the state, researchers have found ways to lessen this impact. As GPS technology continues to advance, it will become an even more viable option for Virginia to consider when deciding to implement a HUF.

Smart Cards are very similar in shape and size to everyday credit cards and either have magnetic strips or contain tiny computer chips that contain information about a vehicle. Smart Cards essentially eliminate the need for wireless
technology because the user physically takes the Smart Card out of the on-board computer located in their vehicle, swipes it at the collection center to transfer the information, and returns it to the vehicle. Enhancing a Smart Card with GPS could give the system the capability to determine where the vehicle was traveling at all times. This data would then be relayed to the Smart Card and transferred at the collection site so time and location could be used to calculate an additional charge. VDOT currently uses magnet strip Smart Card technology at some of its fueling centers across the state to monitor mileage as a precautionary security measure.

The use of an automobile’s odometer to track VMT is another option that Virginia can use to implement a HUF. The odometer can be used to directly report how many miles a particular automobile has traveled in a specified amount of time. This could be accomplished annually at a state inspection or at the time vehicle registration is renewed. It could also take place at a more frequently, such as when the driver fuels the vehicle. When combined with wireless technology, an odometer can transmit mileage data directly to a receiver located on a fuel pump in the same manner a Smart Card does when it is paired up to a card reader. Also like the Smart Card, an automobile’s odometer can be hooked up to a GPS system to track the actual time and locations a vehicle has traveled. The receiver located on the fuel pump calculates the appropriate fee based on the VMT since last fueling and charges the driver accordingly. The level to which GPS is used in conjunction with an odometer technology will determine how fast it could be implemented. The use of GPS will require a significant amount of time to phase in all the technology on all of the vehicles. GPS units will have to be retrofitted on many automobiles and service stations will have to be equipped to read the wireless transmitters. At the other end of the spectrum, if Virginia chooses to implement a HUF that is collected simply by manually reading odometers, the system could be implemented very quickly.

**Policy Issues to Overcome**

It is important to address any issues that may arise because of a HUF through mitigation and education prior to implementation. Whenever a government or regulatory body increases an existing tax or introduces an additional fee, public outcry will be soon to follow. Lessons can surely be learned from the way the abusive driver fee was handled in Virginia in 2007. In order for a HUF to be successful, Virginia will have to make the traveling public aware of the fee through a transparent education program that explains its necessity, the method in which drivers will be charged, and how the fee will be collected. Any potential issues that are identified through research or pilot programs will have to be mitigated against or eliminated altogether.

One of the more sensitive and complex issues that will undoubtedly be raised with the implementation of HUF is the matter of equity. Compared to other funding alternatives, the HUF has the potential to be one of the most equitable because, much like a utility, charges will be based on usage. The more a driver travels, the more they will have to pay. When GPS is used in conjunction with Smart Card or odometer technology, a HUF takes into account the time and location of travel so Virginia can track in-state and out-of-state road usage. Another option would be to use technology that can identify vehicles as they enter and exit the state. London is currently experimenting with this kind of technology by using a close-circuit television and automatic license plate recognition to track vehicles.

It is also important to make sure that a HUF would be as fair as possible to all users. One issue that has been raised is whether or not a HUF unfairly taxes citizens living in rural communities because they typically have to drive further distances than their urban counterparts. Additionally, rural citizens have less transportation mode options available to them, so they are more dependent on automobiles. Lower income drivers would also be impacted because, like the fuel tax, a HUF is regressive and does not take into account a user’s income. Although this cannot be
addressed with any of the available technologies, this issue could be mitigated by funding public transportation with proceeds from a HUF or giving lower income individuals a tax refund based on the number of miles they drove in a particular year.

A HUF has the ability to be somewhat flexible in addressing certain circumstances and issues that currently exist within Virginia's transportation system. For example, it is a fact that heavier vehicles cause more damage to the roadway. Although this is not accounted for in the fuel tax, a HUF can overcome this by charging a higher fee based on vehicle weight or number of axles. There are several different European countries that have been successful in implementing this type of assessment. A HUF also has the potential to address the congestion that is plaguing many Virginia highways. If a GPS system is used, the state can decide to charge drivers more money for driving on congested roads during peak “rush” hours. This theory is similar to the High Occupancy Toll (HOT) concept which is currently being constructed alongside I-395 in Northern Virginia without much resistance from the traveling public. Higher charge will deter drivers from using those troubled roadways, thereby helping to make them less congested.

Another issue to address will be the manner in which a HUF would be collected from alternative fuel vehicles. At some point in the future, it is highly likely that Virginians will be driving vehicles that do not use petroleum based fuels at all so it will be proactive to incorporate collection methods that do not rely on fueling stations. Several of these options include:

1. Collecting VMT at drivers’ residences similar to the collection of power usage by electric companies
2. Uploading VMT data via cellular towers that drivers are required to visit on a periodic basis
3. Obtaining VMT at the time of registration or inspection

There are also concerns that a HUF would decrease the popularity of fuel efficient vehicles, such as hybrids. This is not the case. A HUF simply charges fuel efficient vehicles the same amount as other vehicles for the amount of damage they inflict on the roads. The financial benefits of owning a fuel efficient vehicle will still be realized because owners will still be saving on the price of the gasoline itself.

Although GPS provides many benefits for a HUF, it can also be seen as intrusive and an invasion of privacy. Many users would oppose a system that allowed the government to track the movements of their vehicle in fear that the information could be accessed and used against them in some manner. This can be avoided by using a GPS that was only capable of collecting data for VMT and not location.

### Pilot Study Logistics

Administering one or more pilot studies to gain information on how well a HUF would work in Virginia is important. Additionally, a pilot study can go a long way in gauging public acceptance of the new fee as well. Similar to Oregon, the creation of a dedicated “task force” to help design, administer and analyze the study would be a good way to start. The main goal of a pilot would be examine every aspect of a HUF. Everything from reliability to public reaction towards the HUF must be looked into and analyzed. Doing the pilot in two stages, much like the Iowa study was suggested. Field testing of the different technologies that are immediately available to Virginia could be conducted in the first stage followed by a second stage that analyzes the effectiveness and practicality of each of the technology.

Through the administration of a pilot study the most suitable technologies available to the state could be tested in different localities where test pools could range from 200-300 participants who would be willing to have their cars slightly modified to house the different devices that would read vehicle miles traveled and help determine the HUF. Some of the technologies would also require participants to refuel at certain gas stations that would be fitted with special devices as well. Gas stations and more
specifically gas pumps, will serve as pseudo collection/processing centers for the retrieval and processing of data that devices on automobiles collect for the HUF.

Costs for installing the available technologies in test participant’s automobiles will greatly vary depending on which version of the technology is used and depending on whether or not GPS is used to compliment the devices. The administrative costs for implementing the different technologies will also vary but it has been assumed that they will be higher than the costs of the installation of the devices and the devices themselves. In addition, as previously stated, pumps would have to be fitted with devices that would read and pull important data from the devices that are collecting vehicle miles traveled from autos. While older pumps could not be used for the study, the newer more advanced pumps would only have to undergo an upgrade to their software.

Conclusion

Looking toward the future, Virginia will need to find an alternative revenue source or supplement for the fuel tax in order to maintain a competitive infrastructure system. It only makes sense to collect this additional revenue by charging users for the amount of miles they actually travel, a practice that would be similar to the one that is commonly used in the utility industry. The technology required to implement a HUF is currently available, so there is no reason that Virginia should wait any longer to assess the equity and privacy concerns of its citizens. As in Oregon, Virginia needs to set up a task force to evaluate the technical, economic, and political feasibility of implementing a HUF and decide which pilot program to pursue. The time is now for Virginia to step up as a leader in the arena of transportation and address this issue. If it fails to do so, it could risk being caught off guard and forced to follow the lead set by the states that had already completed their own pilot programs.
Introduction

The condition of Virginia’s infrastructure is integral to the economic future of both the state and the nation. As Ralph Davis points out in the VTRANS Action Plan, “Virginia is strategically located within a day’s drive of one-half of the nation’s population.” (Davis, p.10) Unless transportation in Virginia is adequately funded, the state’s geographic advantage as a hub for commerce will be compromised by congested roads, deficient bridges, and deteriorating infrastructure.

The Current Condition

The purchasing power of the fuel tax, the primary source for road construction and maintenance in Virginia, has been declining in recent years. A spike in fuel prices and overall poor economic conditions have caused the demand for fuel to decrease over the past twelve months, resulting in a further reduction in revenue from the fuel tax at both the state and federal level. (Transportation Budget, p.1) Compounding Virginia’s transportation revenue crisis is the fact that the cost for highway and maintenance and construction has been inflating rapidly. Materials required for construction and maintenance activities such as asphalt, concrete, steel, lumber and diesel fuel has increased by 33% in the last three years alone (TRIP, p.3). To put this in perspective, material prices only inflated 33% over the ten year period between 1996 and 2005. (Virginia Senate, p.3) This deficit is a concern to Virginia more than most states because Virginia has the third largest state-maintained highway system in the country, only trailing North Carolina and Texas. (Financial, 2007, p.163)

In 2006, many of Virginia’s roads were already in need of repairs. Virginia’s Transportation Performance Report for 2006 stated that at that time 11.5% of interstate, 15.4% of primary pavement, and 49% of secondary pavement were deficient. (Virginia’s, p.3) The current condition of bridges in Virginia is even worse. Of the over 12,600 bridges maintained by VDOT, 39% are structurally deficient or functionally obsolete and approximately one-third are more than fifty years old. (TRIP, p.5) The deteriorated condition of Virginia’s highway system cost the average Virginia motorist about $280 each year (totaling over $1.4 billion statewide) for additional vehicle maintenance. (TRIP, p.4)

A safe, efficient, reliable, and integrated transportation system is critical to accommodate population and economic growth while maintaining a comfortable standard of living for current and future Virginia residents. As Virginia’s population continues to increase, so too will the number of registered vehicles, licensed drivers, and vehicle miles traveled (VMT) in Virginia. While vehicle registrations and licensing bring in transportation revenue for the state, Virginia does not currently charge a direct user fee for VMT. Although VMT is taken into account as a result of the fuel tax, the correlation between VMT and fuel consumption is becoming less and less apparent as Virginia drivers begin using a greater number of fuel efficient and alternative fuel vehicles.

A HUF based on VMT is a much more stable source of revenue than the gas tax because it does not depend on the type of vehicle that users choose to drive and it directly correlates with the amount of damage that users do to the roadway. (Wachs, p.7) When more people drive on Virginia’s highways, the roadways become more congested and require greater levels of maintenance. In essence, a HUF will charge drivers for the number of miles they drive in Virginia and apply the revenue collected directly to the cost for the maintenance and construction that is necessary to keep Virginia’s roadways operating at an appropriate level of service.

Scope of the Report

The intent of this report is to assess the technical, economic, and political feasibility of implementing a HUF based on VMT in Virginia and to discuss the logistics of planning a HUF pilot program in Virginia.

Study Approach
This report analyzes and expands upon previous research that has been done within the field of transportation economics that focuses on highway financing by the public sector through user fees based on VMT. The conclusions discovered in the Oregon Pilot Study, the Minnesota Study, the Mileage-Based Road User Charger Study, and the UK Feasibility Study will be discussed and related specifically to the challenges that currently face Virginia. The advantages and disadvantages of odometer based, GPS, and Smart Card technologies will be evaluated. Since Virginia can choose to use any single one or combination of these technologies to collect a HUF, the initial costs, operational costs, and maintenance costs associated with each technology will also be addressed. Public policy concerns about the equity of an HUF and the potential invasion of privacy associated with collection technologies will also be studied. Finally, the report will propose pilot programs that Virginia can implement to further research the feasibility of collecting an HUF.

### Background

The two primary funds that distribute transportation revenue in Virginia are the Highway Maintenance and Operation Fund (HMOF) and Transportation Trust Fund-Construction (TTF-C). The HMOF provides money for maintenance, operations and administration needs, and the TTF-C is dedicated for highway construction. Both of the funds are comprised of state and federal money. State revenues are estimated by the Virginia Department of Taxation, and federal revenues are based on information Virginia receives from the Federal Highway Administration (FHWA). The VDOT Annual Budget dated June 2008 estimated that Virginia received $3.8 billion in revenues to fund the HMOF and TTF-C in Fiscal Year 2008. (VDOT Annual Budget 2008, p.5) As illustrated in the following table, state and federal funding has fluctuated over the last three years:

<table>
<thead>
<tr>
<th>Year</th>
<th>Change</th>
<th>Total</th>
<th>Federal</th>
<th>Per Capita</th>
<th>State</th>
<th>Per Capita</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY2007</td>
<td>----</td>
<td>$3.8 B</td>
<td>$1.2 B</td>
<td>$155.84</td>
<td>$2.4 B</td>
<td>$311.69</td>
<td>$0.2 B</td>
</tr>
<tr>
<td>FY2008</td>
<td>+ 5.9 %</td>
<td>$4.0 B</td>
<td>$910 M</td>
<td>$116.67</td>
<td>$2.5 B</td>
<td>$320.51</td>
<td>$0.56 B</td>
</tr>
<tr>
<td>FY2009</td>
<td>- 5.5 %</td>
<td>$3.8 B</td>
<td>$938 M</td>
<td>$118.73</td>
<td>$2.1 B</td>
<td>$265.82</td>
<td>$0.53 B</td>
</tr>
</tbody>
</table>

* Numbers used in the graphs, and charts were based on VDOT's budget for FY2006-07, FY2007-08, and FY2008-09.
** Per Capita figures are based on June’s 2007 population of 7.7 million and a 1.2% growth for the next two years: 7.8 (2008) and 7.9 (2009) (Metro 1; Demographic 31).
In Fiscal Year 2009, the HMOF is estimated to receive $1.8 billion in funds and the TTF-C is estimated to receive $2.0 billion. In addition to construction ($984 million), the TTF-C will be distributed to pay for debt service ($271 million), payments to other agencies ($535 million), and special financing ($317 million). (VDOT Annual Budget 2008, p.1).

Virginia’s Current Revenue Sources

The motor fuels tax, the motor vehicle sales and use tax, the motor vehicle license fee, and the state sales and use tax are all currently collected in Virginia to specifically fund transportation (VDOT Annual Budget 2008, p.1) Graph 1 illustrates the distribution of these revenues to the HMOF and the TTF-C in Fiscal Year 2008 and Fiscal Year 2009.

Graph 1:

Revenues

* Included in other sources are CPR bonds, PTF, and toll facilities revenues
States Motor Fuels Tax

In 1923, Virginia enacted the first state fuel tax at a price of 3 cents per gallon. (Williams, p.3) Since that time, the Virginia fuel tax has increased to 17.5 cents per gallon for gasoline and 18.4 cents per gallon for diesel. The revenue raised by the tax on gasoline is split between the HMOF and the TTF-C so that 14.85 cents of each gallon is dedicated to the HMOF and 2.5 cents of each gallon is set aside for the TTF-C. Based on recent data of motor fuels tax revenue, it can be estimated that for each penny of the gasoline tax approximately $50 million in tax revenue is generated. (VDOT Annual Budget 2008, p.1)

One of the reasons a motor fuels tax is unreliable is because revenues from it are adversely impacted when high oil prices cause VMT to decrease on roads throughout Virginia. Additionally, the gasoline tax, per gallon, does not adjust for inflation, time of day, or type of vehicle being driven. This diminishes the purchasing power of revenues collected from fuel taxes because it does not take into account the actual amount of damage vehicles do to the entire roadway system.

VDOT’s Annual Budget for 2008-2009 projects the total motor fuels tax to equal $869,957,700. One of the Virginia Department of Taxation’s Chief Economists John Layman points out that after adjusting this amount for inflation the state’s motor fuels tax collections are still the lowest they have been in twenty years. (Bacque, p.1) Virginia State Senator, Charles J. Colgan, expanded upon this fact by stating in a presentation during Virginia’s Second Special Session in 2008 that, “since 1986, the purchasing power of the gas tax has eroded 95% due to inflation, thereby compromising the state’s ability to build and maintain roads.” (Colgan, p.3)

Motor Vehicle Sales and Use Tax

Virginia receives a 3% vehicle sales and use tax whenever a vehicle is sold in the Commonwealth. (Economic, p.4-1) Until recently, this tax raised approximately $570 million annually for the HMOF and the TTF-C. (VDOT Annual Budget 2008, p.1)

Unfortunately, the sale of automobiles has been impacted by the recent economic conditions, including the credit crunch, the rising unemployment rate, a low wage growth, and the deterioration of the housing market. Appendix C shows that Virginians are buying fewer automobiles and at cheaper prices. (Layman, p.6)

Although the VDOT Annual Budget for Fiscal Year 2009 projected the revenue from motor vehicle sales and use tax to be $539,612,600, that figure may be too high. Revenue from the vehicle sales and use tax fell by a double digit percentage for the fourth consecutive month in August of 2008, and the year-to-date tax collections are down 16.9 percent. (Commonwealth, p.1) Appendix B shows that revenues from the motor vehicle sales tax declined by more than $50 million dollars between Fiscal Year 2007 and Fiscal Year 2008, and are expected to decline by even greater margins in Fiscal Year 2009 (Layman, p.5). The reality that revenues from the vehicle sales and use tax are declining coupled with the fact that the vehicle sales do not accurately project infrastructure maintenance and construction needs suggests that this tax is not a reliable funding source either.

Vehicle License Fees

The current vehicle license registration fee of $29.50 is mandated by the Code of Virginia and a majority of the fee is allocated specifically for the HMOF and the TTF-C. In Fiscal Year 2008, the revenues collected by the vehicle license fee were $11.0 million less than what had been estimated in the budget. HB3203 sought to increase transportation funding by raising the vehicle registration fees so that an additional $89.4 million would be collected for the HMOF alone beginning in Fiscal Year 2009. (Financial, 2007, p.24) All told, the VDOT Annual Budget for Fiscal Year 2009 estimates that $253,535,300 will be collected in vehicle registration fees.

Retail Sales and Use Tax
The current retail sales and use tax is 5% in Virginia. Prior to 2008, the transportation funds received 10% of all revenues raised by this tax. In March of 2008, the amount funding the transportation funds received increased to 32% of all revenues raised by the retail sales and use tax in March of 2008. (Commonwealth, p.1)

The amount of revenue from the retail sales and use tax projected in the VDOT Annual Budget for Fiscal Year 2009 is $468,579,800.

International Registration Plan Fee

Since Virginia is one of the thirty-nine states that participate in the International Registration Plan, truck drivers that pass through the Commonwealth have to pay certain fees based on vehicle weight and the number of miles driven in Virginia. The registration that interstate motor carriers have to pay increased by 37.2 percent on July 1, 2007, and is captured in Fiscal Year 2008 data. (Economic, p.4-3)

This fee generated $64.5 million in transportation revenues for Virginia in Fiscal Year 2008 and is projected to generate $66.6 million in transportation revenues in Fiscal Year 2009. (Budget, 2008, p.7)

Federal Revenue

When the United State Congress enacted the one cent excise tax on gasoline in 1932, it became part of the federal general revenue fund. The federal fuel tax remained a part of the general fund until 1956 when the Federal Aid Highway Act was passed and established the Highway Trust Fund (HTF) and required all revenue from the federal fuel tax to be entered into the HTF. Between 1956 and 1982, 100% of the HTF was used to finance federal highway programs. In 1982, however, 20% of the HTF was allocated to support mass transit improvement projects. (Buechner, p.1-2; Williams, p.6-8). The federal fuel tax currently makes up approximately 87% of the HTF. The federal government helps to fund state transportation projects by offering an 80/20 federal to state match on most primary and interstate road project as long as all federal guidelines are followed. Although federal revenues only represent about 45% of capital investments on current state projects throughout the nation, that figure is expected to increase as state funds become scarcer. (Lee, p.9) Total federal revenues projected in the VDOT Annual Budget for Fiscal Year 2009 are $938,473,644.

Transfer of Revenues

Virginia transfers millions of dollars from the TTF-C to the HMOF each year. This is because state law requires VDOT to fully fund maintenance operations before funding the construction of any new infrastructure (Six Year 1). VDOT’s Chief Financial Officer, Reta (RITA?)Bucher described the impact that these transfers have on Virginia’s roadway network in a report to the Commonwealth Transportation Board (CTB) on February 20, 2008. She stated that, “state construction funds will become unavailable to fully support the needed HMOF transfer beginning in Fiscal Year 2016.” By spending less on construction, Virginia will receive less federal match funds for construction projects, and Virginia’s roadways will become even more congested. In VDOT’s Annual Budget for Fiscal Year 2009, $384,970,350 is estimated to be transferred from the TTF-C to the HMOF.

The Transferring of funds occurs not only between the two state highway funds, but also between transportation and non-transportation programs. In the past, transportation revenues have been diverted to the General Fund to support non-transportation functions during times of fiscal crisis. In Paying at the Pump: Gasoline Taxes in America, Jonathan Williams said that leading transportation analysts “estimate that total diversions of gasoline tax dollars away from legitimate general road use equal nearly 40 percent of total fuel tax revenue (Williams, p.13).” Delegate Bob Marshall said, “In the last twelve years, over $1.2 Billion has been diverted from this fund [Transportation Trust] to fund other non-transportation purposes (Marshall, p.1).” In fact, just a few years ago, then-Virginia Governor Mark Warner moved $317 million from the transportation funds (Marshall, 1).

Toll Facilities

VDOT operates and maintains three major toll facilities in the state. The revenues that are
collected by tolling these roads are incorporated into the Special Revenue Fund and the Debt Service Fund and are used to operate, improve and maintain the facilities, and well as pay off any lingering bond principal and interest. (Financial, 2007, p.76). Revenues from the three VDOT operate tolls are estimated to exceed $77 million in Fiscal Year 2009 according to the current VDOT Annual Budget FY2009

Sources of Revenue for the HMOF & TTF-C

The following two graphs illustrate how the revenue streams described above as well as those from bonds and localities are used to compose the HMOF and the TTF-C in Virginia:

Graph 2:

![Graph 2: HMOF Revenue Source](image)

* Numbers used in the graphs, and charts were based on VDOT’s budget for FY2006-07, FY2007-08, and FY2008-09.

Graph 3:

![Graph 3: Construction Revenues by Sources](image)

* Numbers used in the graphs, and charts were based on VDOT’s budget for FY2006-07, FY2007-08, and FY2008-09.
Analyzing the Feasibility of a Highway User Fee for the State of Virginia

* Bond revenues ($227,100,000) are generated from the issuance of governmental bonds and are used to pay debt services on the bonds, interest to bondholders and retiring bonds on maturity. (Revenue, p.3)
* Local revenues ($97,299,317) include sources such as revenue sharing, coal severance tax, anticipated local construction funds, participating project costs, urban construction project participation, other locality contributions/match and public right-of-way use fee
* Special sessions funds ($708,229,159) include the motor vehicle fuels tax, motor vehicle sales tax, vehicle rental tax and state retail sales and use tax (Annual Budget Supplement, p.2)
* TTF-C revenue sources are distributed to the following categories: construction projects ($984 million), debt services ($271 million), transfers to other agencies ($535 million), and special financing ($317 million). (VDOT Annual Budget 2008, p.1)

From 2005-2025, Virginia’s will need approximately $203 billion to adequately operate and maintain Virginia’s current roadway network. Since the estimated revenues for this time period are on $95 billion, transportation expectations will have to be lowered, or funding for infrastructure will have to increase to meet the demand. (Davis 5)

Alternative Revenue Sources
Virginia Department of Transportation Commissioner, David Ekern, estimated that VDOT programs will be reduced by $2 billion to $2.5 billion between Fiscal Year 2009 and Fiscal Year 2014 due to the recent economic slowdown. (A Blueprint-VDOT Response to a Declining Economy, 3) In order to keep Virginia roads from deteriorating any further, state leaders must act now to reduce this shortfall by finding additional sources for transportation funding.

Although the fuel sales and use tax could simply be increased to raise additional funds, that is not a politically viable nor efficient solution. Gasoline taxes no longer fit “the benefit principle of taxation” because consumers are no longer being directly taxed in proportion to the benefits that they receive (Williams, p.2). A future revenue source should charge drivers for the damage and congestion they cause to Virginia’s roadway network. The technical, economic, and political feasibility of implementing a HUF that can directly charge drivers for the number of miles they travel will be discussed in the remainders of this report.

A Highway User Fee based on Vehicle Miles Traveled

The concept of charging drivers based on the number of miles they drive is one that has been well researched and documented both nationally and throughout the world. This system offers a new method of transportation financing and provides an alternative to the gas tax. Forkenbrock and Hanley (2006) assert that, “with the advancement of global positioning system (GPS) and geographic information system (GIS) technology, a new approach to directly charge users has become more feasible. Now it is possible to accurately access road user charges on the basis of the number of miles actually traveled.” (p 6)

Risks and Benefits of a HUF
Since a HUF is derived from the amount of miles a vehicle travels on the roadway, it provides a revenue stream that will proactively address any future advancements in vehicle propulsion technology. The popularity of fuel efficient and alternative fuel vehicles will have a negative impact on the transportation revenues that are generated by the fuel sales and use tax unless a HUF is set in place that can accurately capture all vehicle types. A HUF will provide Virginia with a reliable projection for financing improvements and maintenance of the road systems well into the future. By deriving a HUF that is totally dependent on driver behavior, however, transportation revenues in Virginia are still at risk because they will fluctuate based on the number of miles driven in Virginia. The Department of Transport study of road pricing in the UK points out that, “by signaling to users the costs of travel, people will decide that for some of their journeys they will change the way in which they make these trips” (p. 32). As drivers become aware of the trip mileage costs, their road choices may change. This issue is compounded when the price of travel (other than a HUF) drastically increases and users are forced to justify cost savings by driving less.
HUF Enhancements

If the state of Virginia decides to implement a HUF, enhancements to the fee that would address congestion and pollution could be considered as well. As the Oregon final report (2007) stipulated, “Congestion pricing (also referred to as peak period pricing, road user charging or value pricing) assesses the owner/operator of a motor vehicle a charge for using certain roadways during periods of high congestion.” (p 3) An HUF based on GPS could take into account congestion zones that occur during peak period driving. This would allow Virginia to charge drivers differing per-mile rates depending on the time of day, the road being used, and the designated congestion.

Congestion pricing could also be applied so that the rate would change when the classification of the road changes. This enhancement could help reduce traffic passing through residential neighborhoods and may also discourage heavy vehicle travels from traveling on roads that are not designed to carry them. This alternative to the user fee may have a positive effect on safety. Another benefit may be the reduction in costs associated with maintenance and construction repairs on inferior roads that are built for light vehicles. (Forkenbrock 2004, p7)

A study completed by the European Commission entitled, Environment and Climate Research Programme, suggests that the emission of greenhouse gases will decrease between 13% and 24% if an HUF is implemented in conjunction with congestion pricing. This is due to the fact that congestion pricing will reduce the number of cars that are idling in traffic during peak hours.

Another benefit of a HUF is that Virginia could use the information from a GPS based system to calculate the number and type of vehicles that drive on each road throughout the Commonwealth. This information will help VDOT better plan maintenance and construction activities by providing a means by which to prioritize spending on roads based on their actual use.

Previous and Ongoing Studies – Oregon Pilot Study

In the early part of the 2001 Oregon legislative session, automobile manufacturers demonstrated alternative fuel vehicles to the Oregon House Transportation Committee at the request of the elected officials. Realizing the possible vehicle evolution in the coming years, these legislators began addressing a possible shift in tax revenues. They recognized that the state primarily depended on revenues generated by the gas tax which motivated them to contemplate the long term implications on the Oregon road system. Their concern about gas tax revenues eroding in the future and its effects on the road system led them to introduce a proposal that addressed this issue by studying the feasibility of a HUF.

The state of Oregon passed legislation in 2001 that created the Road User Fee Task Force (RUFTF) and gave the responsibility of administering and implementing a pilot project to the Oregon Department of Transportation (ODOT). As the Oregon Department of Transportation’s Final Report on Oregon’s Mileage Fee Concept and Road User Fee Pilot Program (2007) stipulated, this task force was assigned the duty of “developing a new road revenue system alternative to the gas tax” (p. v). The focus of this innovative concept was on road usage and coming up with a charge that can be directly correlated with an individual driver’s actual use of the road system. The report (2007) goes asserts that, “...the amount paid would be a “fee for service” rather than a general tax unrelated to use” (p. v).

Over the course of the next two years, the task force explored 28 possible revenue ideas and subsequently presented the Oregon Mileage Fee Concept in March 2003, as a model for meeting the goal of creating a new revenue system. As the report (2007) indicates, “…the task force recommended that the ODOT conduct a pilot program to study two strategies called the Oregon Mileage Fee Concept”:

1. Study the feasibility of replacing the gas tax with a mileage-based fee based on
miles driven in Oregon and collected at fueling stations; and
2. Study the feasibility of using this system to collect congestion charges. (p. vi)

The responsibility of conducting a pilot program that would test the viability of this concept was assigned to ODOT. Over the course of the next three years ODOT prepared for the pilot study and contracted with Oregon State University (OSU) and Portland State University (PSU) to conduct the research and develop viable collection and technical tools to use in the mileage fee testing. (Final Report, p. 6)

One of the collection options that received serious consideration was a central collection center; however, Oregon learned that “central data collection and billing centers become surprisingly expensive to operate when extended to a mileage fee system employed statewide rather than at a single high volume facility” (Final Report, p. 6). The other collection idea that met the criteria and that would ultimately be used in the field test “was an electronic accounting and communications system ODOT calls Vehicle Miles Traveled Collected at Retail (VMTCAR)” (Final Report, p. 7). This method has a wireless electronic system on the fuel pump that reads the vehicle’s on-board global positioning system (GPS) to determine geographic zones that a vehicle has traveled in (assessing miles driven only in the state) and calculates the total miles driven since the fee was last collected using the vehicle’s odometer. The bill generated at the gas station point-of-sale (POS) tabulates the mileage and applies the appropriate rate per mile and then subtracts the gas tax for the net total fuel purchase so the user is not taxed twice.

ODOT launched the 12-month pilot program in April 2006 with 285 volunteer vehicles, 299 motorists and two service stations located in Portland (Final Report, p. vi). The pilot program was evaluated based a set of criteria formulated by the task force:

1. Administration
   • Ease and cost enforcement
   • Utility

2. Cost
   • Start-up costs: capital and retrofitting
   • Operating and maintenance
   • Enforcement and auditing
   • Cost of collection relative to fuel tax

3. Net revenue generation potential
4. Hardware and software
   • Availability
   • Feasibility
   • Accuracy
   • Reliability
   • Security
   • Expandability
   • Interoperability
5. Systemic precision
6. Evasion potential
7. Usefulness for phasing and partial implementation
8. Adaptability to congestion pricing
9. Public Acceptance
   • Costs to vehicle owner/operators
   • Ease and convenience to vehicle owners
   • Privacy protection
   • Fairness
   • Transparency
   • Aversion/attraction (Oregon’s Mileage Fee Concept and Road User Fee Pilot Program: Final Report, 2007, p. 13).

The pilot program report confirmed that the administration of the mileage fee concept “provides a cost effective and useful deterrent against fee evasion” (p. 26). Since the system was collected at fuel pumps, the fee diverted back to the gasoline tax if the transmission of mileage data failed. This proved that an HUF was capable of replacing the gas tax as well as coinciding with continued gas tax collection. The 2007 report concluded that a fee based on mileage was both administratively and technically feasible. Specifically, “the pilot program demonstrated that ODOT could implement calculation and collection of a mileage fee with no additional actions required from motorists or service station attendants, and that congestion-based fees may be easily
incorporated into the system” if GPS is used (p. 37).

An economist for ODOT estimated that the capital costs for implementing a statewide HUF similar to the one studied in the pilot program would cost in the neighborhood of $33 million. These costs included items such as the vehicle hardware, software and installation of equipment, service station fuel pump devices, and administration overhead. The projected costs of operating, maintaining, enforcing and auditing the system were estimated in 2003 to be approximately $1.6 million each year. The potential revenue generated by the mileage fee will be subject to the rate passed by the legislature. The 2007 report postulated that, “the mileage fee implemented statewide would begin to generate more revenues than what the gas tax would be expected to generate since the gas tax erodes because of improvements in vehicle fuel efficiency, while the mileage fee does not” (p. 33).

Although most of the vehicle hardware and software needed for the field test was available, the fuel pump equipment had to be developed during the program. As technology advances, it is probable that cost-effective equipment will be available and this should not pose as a deterrent for the implementation of the HUF studied in Oregon. It is important to note, however, that security, expandability and interoperability of the system was not studied in the Oregon program and therefore the study recommended that further testing has to take place before the system could be rolled out statewide.

Since retrofitting vehicles has the high potential for increased administration costs, ODOT anticipated that it would instead have to rely on the new vehicles being equipped with the technology and phase in the HUF accordingly. Vehicle purchases over the ensuing years would replace cars that did not contain the necessary on-vehicle devices. The participants in the field test felt that the mileage fee system was easy to use and 91% said they would keep the equipment and pay the mileage fee all gas stations were equipped to collect the fee.

Privacy was one of the participant’s main concerns. The pilot study sought to maintain privacy by not retaining the data associated with trips or location and only maintaining the number of miles driven and relevant vehicle identification information. In addition the drivers in the study came to a better awareness of the fairness of the mileage fee concept in comparison to the gas tax. Other important aspects of the field test showed that the participants appreciated the transparency of ODOT who explained the mileage fee system and provided information about the pilot program throughout the field testing.

The conclusion of the concept pilot program was that technological advancements have made the mileage fee a viable revenue source alternative for replacing the fuel tax and will provide a feasible source for road funding.

The State of Oregon was able to develop the mileage fee concept and conduct field testing of the road user fee pilot program with the financial assistance of the federal government. The report (2007) noted that, “The Federal Highway Administration (FHWA) funded the bulk of the project with three targeted grants through the Value Pricing Pilot Program, totaling $2.1 million for over six years; the State of Oregon contributed $771,000 in matching funds” (p. 21).

The final report (2007) outlines the next phase in realizing the road user mileage fee concept and its implementation in the State of Oregon. The study acknowledges that, “… additional development and testing would have to take place to prepare for full implementation:

- ODOT would have to work with technology firms and automobile manufacturers to refine on-vehicle technology, and work with the fuel distribution industry to insure ease of mileage fee transactions at the fuel pump.
- ODOT would have to expand the concept to include home fueling collections and multi-state integration.
ODOT would have to develop cost estimates for full implementation, which could occur within the next 10 years.” (p. vii)

Oregon has conducted a pilot program to assess the feasibility of replacing the gas tax with a vehicle mile user fee. Through trial and error over the course of six years, the task force and the ODOT came up with a field tested application that confirmed the viability of this innovative funding method. The State of Virginia may use the information gathered from this ODOT mileage based user fee study as a guideline for engaging in a similar analysis.

The Virginia Department of Transportation (VDOT) may also have a less time consuming and streamlined investigation of the mileage based user fee because of the groundbreaking work completed by the State of Oregon. Contacts with the Oregon representatives involved in the pilot program by pertinent state officials and VDOT personnel may assist in better understanding the best approaches to take in researching this alternative revenue source. Exploring options like the mileage based user fee will help Virginia maintain the status as an innovative and progressive state in seeking new alternatives for funding the maintenance and improvement of the road system.

Minnesota Study

The Minnesota Department of Transportation conducted a mileage-based user fee research project titled Pay-As-You-Drive (PAYD), with the help of a consultant Cambridge Systematics, submitting the results in a March 2006 final report. This project was co-sponsored and funded by the Federal Highway Administration (FHWA) and the Minnesota Department of Transportation. Buxbaum (2007) noted in the final report that the goal of this research was to present, “a demonstration to test how consumers would change their driving behavior if some of the fixed costs of owning and operating a car were to be converted to variable costs” (Abstract). The study consisted of a qualitative element that conducted market assessment surveys of the general public to better determine interest in a pay-as-you-drive pricing alternative to vehicle fixed costs such as leasing and/or insurance. The research also had a quantitative element that recruited participants in a simulated pay-as-you-drive pricing experiment.

Buxbaum also pointed out that the overall objectives of the project were to:

1. Simulate the replacement of the fixed costs of vehicle ownership and operation with variable costs that give drivers explicit price signals about travel decisions and alternatives;
2. Develop the best possible understanding of transportation price elasticities and how they vary by vehicle ownership/lease arrangement, income, location, annual mileage driven, and other factors;
3. Develop an understanding about driver acceptance of use-based fees and appropriate price signals necessary to affect travel behavior changes; and
4. Identify strategies and recommendations that might be employed to mainstream or institutionalize policies or techniques learned from the demonstration. (p. ES-1)

The experimental testing of this study took place in the Minneapolis/St. Paul metropolitan area and began in February 2004 and concluded in February 2005. One hundred and thirty households participated in the research, broken down by one hundred participants being subject to pricing and the remaining thirty people as the random control group with no pricing. A CarChip was installed in the participant’s vehicle, which electronically monitored each trip taken, the time that the vehicle was driven, and the mileage of the trip. Another parameter of the study was to “test the mileage reduction differences at different times of day, some respondents were priced at higher per-mile levels during the weekday peak periods than at other times while other respondents were priced per mile the same amount at all times” (Final Report, 2006, p 2-8).
The data was compiled for two months to calculate normal driving patterns and to set mileage budgets. At this point half of the 100 pricing drivers were given a pricing experiment based on a per-mile rate and the other half was not priced. The participants were assigned a simulated per-month budget based on their miles driven. If they drove over the allotted mileage, their account was left at zero, but if they reduced their mileage, the driver could keep the amount left in the account that month. As the final report (2006) indicated, “A key element in the study was how participants respond to price signals regarding the cost of their driving” (p. 2-7).

The final report (2006) observed that the results of the experimental testing showed:

- Wide-scale per-mile pricing would result in a measurable, but small reduction in vehicle mileage.
- The biggest reduction in mileage would be on weekends, but weekday peak-period travel would be reduced by more than weekday off-peak period mileage.
- Mileage reductions from per-mile pricing would vary by season, with the highest reductions during the summer.
- There were household variances for mileage reduction. Households that could reduce their mileage the most are those that:
  - Have other unpriced vehicles to which they could transfer their trips;
  - Have leased vehicles, probably because they are more accustomed to monitoring the mileage on vehicles; or
  - Have household members that actively think about auto ownership and operating costs.
- Households that are less likely to reduce their mileage under per-mile pricing are those that:
  - Have a head of household who is more than 65 years old.
  - Higher per-mile charges do not necessarily seem to increase the mileage reduction of households. (p. ES-7 & 8)

The concept behind pay-as-you-drive pricing is to increase the automobile user’s knowledge and awareness of the per-mile cost of traditionally fixed cost products. As the consumer becomes more attentive to the costs associated with the per-miles driven, the travel behavior may be altered. One of the goals of the pay-as-you-drive concept was to assist the automobile user in gaining a better understanding of the real costs of driving. Additionally, the report indicated that it will, “provide another public policy management tool to help in reducing or managing auto travel” (p. 1-2).

The August 2007 Minnesota Mileage-Based User Fee Public Opinion Study revealed that, “In general these participants did not fully grasp the amount of tax dollars they spend per year on the transportation system, nor do they easily recognize the sources through which these monies come” (Executive Summary). The experimental field test conducted by the Minnesota Department of Transportation provided the traveling public with information and awareness concerning the direct correlation between the use of the road and the mileage fees associated with this use. The State of Virginia may also benefit from a study program that assists its citizens with an increased knowledge and understanding about how their vehicle use is directly linked to the cost of using the road system.

**Mileage-Based Road User Charge Study**

A three year study from 1999 to 2002 was the beginning of analysis into a national evaluation of a mileage-based road user charge. It started with an initial research phase that as Forkenbrock and Kuhl (2002) wrote, “was funded by the Federal Highway Administration and a special consortium of the departments of transportation serving fifteen states. Contributing states include California, Connecticut, Iowa, Kansas, Michigan,
Minnesota, Missouri, North Carolina, Ohio, Oregon, South Carolina, Texas, Utah, Washington, and Wisconsin” (p. v). The focus of this part of the research that “studied a wide range of issues related to the development and implementation of a mileage-based charge as an alternative to the current motor fuel tax and developed an initial architecture for a mileage-based road user charge system” (The University of Iowa’s Public Policy Center, PowerPoint, p. 4).

The University of Iowa Public Policy Center received a $16.5 million federal grant in 2005 to conduct a national field test that will explore the viability of implementing a mileage-based road user fee system. The objectives of this second phase of the study listed by The Public Policy Center (2008) include “assessing the feasibility and efficacy of replacing the current motor fuel tax with a mileage-based user charge” and also addressing key issues such as “technology, privacy and security, transition/phase-in, public policy ramifications, and public acceptance” (PowerPoint p. 2).

The field test, scheduled to begin in 2008, is now underway at six different regional sites around the nation (San Diego, CA; Boise, ID; Eastern Iowa; Austin, TX; Baltimore, MD; and Research Triangle, NC) and is scheduled to conclude in two years. There will be approximately 2,700 participants nationally, with 450 programmed to take part at the individual sites. The participants also will have mileage-based technological equipment temporarily installed in their vehicles for about 10 months.

A professor associated with this study described the technological aspects of the system. Kuhl (2007) pointed out that a participant’s vehicle will be equipped with a GPS system that ascertains the location and an on-board computer maintains files that contain the boundaries the vehicle travels in and stores the per-mile road user charge data (Project Overview). This data will then be sent on a predetermined date to a billing center, much like an electric bill. This charge is then forwarded to the vehicle owner for payment.

This field test seeks to determine the effectiveness of the technology. Kuhl emphasized that, “We need to be absolutely certain that the technology ultimately used is cost-effective, reliable, user friendly, flexible, and secure” (Project Overview).

Another issue that the study seeks to clarify about the mileage-based road user charge is the user compatibility. Feedback throughout the life of the study is critical to the overall success of this new alternative revenue source. The assurance of privacy will remain a key component in its implementation. The system will also need to be convenient to the user in regard to the technology and the billing process. Field testing this innovative approach to transportation funding will provide vital information in the ongoing process of determining a new method for future financing of the highway system.

As this field test has just begun, information related to the ongoing developments in the study process will be forthcoming. To obtain updates and learn additional details related to the status of this research, go to the web site at www.roaduserstudy.com, or call the toll free phone number at 1-866-363-1975. (University of Iowa Public Policy Center)

One of the ways that the State of Virginia may profit from the mileage-based road user charge study is through the diversity of geographic areas that are participating in the research. This widespread field test will assist in determining the feasibility of implementing the user fee on a state by state basis. It will also provide an avenue for exposing the concept to the general public, which will enable Virginia to promote road pricing as possible alternative to the fuel tax. As used in this study, the application of federal grants for future research will provide the State of Virginia the funding needed if it seeks to conduct its own research into road pricing.
Feasibility Study of Road Pricing in the UK

The vehicle-miles-traveled user fee concept has garnered interest in states such as Oregon and Minnesota and is also receiving national notice and field testing mentioned previously. The issues surrounding a long term solution to financing highway transportation is not confined to the United States. The concerns about having the resources necessary to meet the projected travel demands have caused others to assess this problem. Looking for new highway funding approaches, the United Kingdom has also tried to determine the viability of road pricing.

In an attempt to provide answers, the Department for Transport embarked on a feasibility study of road pricing in the UK. The full report (2004) stipulated that it is “set up to consider whether it would be feasible to change the way we pay for roads, so as to bring about a more efficient and less congested roads system. A new system of road pricing would mean moving away from the current motoring taxation system, and introducing charges to use roads that vary depending on how congested they are” (p. 2).

The focus of this study dealt with road pricing capabilities and not its implementation. The report (2004) evaluated the following items “to address whether and how road pricing might work:

- Feasibility in terms of the degree of public acceptance pricing might have, and the determinants of public opinion
- The ‘why?’ – the wider transport context, the trends in traffic and congestion that are forecast without pricing, and the drivers of congestion in terms of the travel choices people make
- The ‘how?’ – the technological practicalities of applying road pricing, based on an assessment of the way technology is developing, how pricing might work, and the modeled impact it might have, and identifies the factors that would need to be taken into account in scheme design
- The ‘who and what?’ – Who would need to do what, the different roles for central and local government. Who exactly would decide to implement a scheme, set the charges and spend the revenues
- The ‘when?’ – how soon might it be possible to establish a national scheme and what might be done in advance of that (p. 6-7)

The research into whether or not the public will accept road pricing revealed that, “people need to agree that it would deliver a solution to a problem which they can see needs addressing” and that trust is vital. “People need to be confident that road pricing is designed to deliver transport and other benefits, rather than a means of raising more revenue” (Full Report, p. 8). Public agreement about road pricing must overcome the notion that the primary purpose of governmental bodies is increased revenues as opposed to a reasoned approach for revenue accrual that meets the demands for upkeep of the road system.

The incorporation of road pricing in the UK as a means of reducing congestion is thought to have more of an effect than the fuel tax. A change and or reduction in the traffic patterns may have a positive affect for citizens and commercial enterprises. As the report (2004) indicated, the ability to “differentiate between times and places, as well as distance, it [road pricing] can target congestion when and where it is happening, rather than overall traffic levels” (p. 18). An alteration in travels patterns made possible by road pricing may provide congestion relief, increased safety, and environmental improvements, leading to overall economic benefits due to the better flow of traffic.

Charging for the use of a particular stretch of road within a given area in the UK is not new. One of the methods of assessing fees that currently take place is cordon pricing which charges the driver when they cross or enter an urban boundary. Another system, familiar to most in the U.S., is tolling certain structures
and/or roadways. These types of charging schemes provide infrastructure revenue; however, they are confined to time and space. The pricing coverage is limited to the particular applicable infrastructure and the vehicle mileage traveled is also not captured. The missing element is distance. The full report (2004) enumerated the advantages of adding the distance traveled to the elements of time and space.

- Road users can make choices influenced and informed by pricing signals throughout their journeys, rather than just once or twice a day
- Short [and long] journeys are recognized as such. ...charging relates much more closely to the use made of the network and the real contribution that a vehicle makes to congestion and other environmental effects, and, as a result
- Much better use is made of road capacity (p. 21)

Implementing a pricing system that is capable of integrating time, space, and distance will require complex technological equipment. Key components of these systems must include accuracy, reliability, and privacy. The report admitted that such advanced technology is currently not available to the mass market; however, it encouraged the involvement of the UK Government in promoting the manufacturing and development of the technological equipment needed.

Decisions made involving the development of a road pricing system would need to include all levels of government in the UK for the local to the national level. Issues that need to be addressed by the government in preparing this scheme include: legislative approval, setting a fair and equitable rate, improving the technological capabilities, smooth transition from a fuel tax to a road pricing approach, ensuring privacy, and guaranteeing a well run program when it is in place. The government also needs to have a road pricing scheme with a clear purpose that the general public can readily grasp and understand. An open and straightforward approach throughout the road pricing development process will also improve the likelihood of a successful implementation.

Assessing the complexities of the issues involved in realizing a national road pricing scheme, the full report (2004) acknowledged that, “while there are actions that could be taken in the meantime to facilitate it, a feasible scheme is still a decade or so away from operation” (p. 38). This does not mean that no action will be taken. One the initiatives that the government is planning to unveil is the “Lorry Road User Charge” which is “a system of distance charging for all goods vehicles using UK roads” (p. 39). In addition there will continue to be the use of certain road charging such as cordon and tolling to help alleviate congestion.

The report encourages taking a proactive approach in the move toward road pricing. Addressing technological advancements, the full report (2004) suggested that, “Implementing some would offer solutions to congestion problems that we face on our roads today, improve our knowledge of road pricing, and demonstrate to a wider public the benefits that a national road pricing scheme could eventually deliver” (p. 42).

One of the conclusions of this report noted that even though road pricing is not yet technologically feasible in the UK, as the advancing technology continues to improve, it will only be a few short years away. Another observation was that this new method of revenue would be sufficient to meet the financial transportation needs of the government, but it needs to begin laying the groundwork for its implementation. The study makes governmental recommendations that include a strong public relations endeavor, reaching out to the affected industries (e.g. car and IT manufacturers), and crafting a development design for possible future execution of this revenue scheme.

Finally, another crucial feasibility element of road pricing is cultivating a positive public perception and ultimately their acceptance of the road pricing system. The study admitted:
“road pricing is not well understood as a concept and most people’s reaction is that it means paying more to do something that so far they have thought of as being free. Acceptability would be influenced by many factors including the design of the scheme, the level of charges, the way the scheme fitted with wider measures, and what use was made of the revenue.” (p. 45)

All of these issues will have a deciding factor on whether and how road pricing might work.

One of the overriding issues for road pricing feasibility in the UK study was public acceptance. Realizing the difficulty of implementing a new approach that replaced the fuel tax, the report emphasized the importance of open discussion and providing understandable information about this scheme. The State of Virginia would be well advised to follow the example from this research in reaching out to the public in a transparent and straightforward manner about road user fees. The report also encouraged a proactive approach in seeking a solution for road infrastructure funding. As Virginia seeks resolutions for financing its highway system, it will be important to maintain a dynamic vision for future road funding alternatives.

**A HUF in Virginia**

Virginia continues to explore new ways of financing roads. An innovative approach that seeks to mitigate congestion is the High Occupancy Toll (HOT) lanes in northern Virginia. These lanes provide a choice for travelers by allowing vehicles that have the requisite passengers toll-free passage, while the single occupant vehicles pay the toll. Virginia already has High Occupancy Vehicle (HOV) lanes that may be used as a transition to HOT lanes.

Virginia is also a state that continues to welcome businesses. In 2007, Governor Kaine announced that, “Virginia has been designated as America’s most business-friendly state in the annual independent study Top Ten Pro-Business States 2006: America’s Economy in the 21st Century” (Press Release). Touting the positive attributes of the state, Badenhausen (2006) remarked in a Forbes Magazine article that, “Add up a smart labor force, low costs, good regulatory environment and a great quality of life, and you get Virginia, the runaway winner in our listing of the Top States for Business”.

Virginia also remains a fiscally responsible state. It continues to maintain its high bond rating as noted in the official Virginia state website; “Virginia’s AAA bond rating, the best rating possible, is a reflection of the confidence placed in the Commonwealth’s fiscal health” (Virginia.gov). An article announcing the 2008 bond rating from Fitch Ratings (2008) stated, “Virginia’s ‘AAA’ rating reflects its substantial resources, conservative approach to financial operations which include periodic revenue forecast updates, and careful attention to the level of its debt obligations” (Business Wire).

The VMT user fee may assist the Commonwealth of Virginia in sustaining the business-friendly environment and retaining the strong bond ratings through a stable and reliable revenue stream that will fund the operation and maintenance of the state’s highway transportation infrastructure. A reliable, sustainable source of funding for the highway system will reduce the drain on the general state budget, while providing for the long-term work on the road system. The State of Virginia may explore alternative road funding sources like the VMT user fee that will provide a strong transportation system. A vibrant, well maintained infrastructure is one indication of having a sound, fiscally responsible state that will support a business friendly environment.

**Technical Feasibility of a HUF**

The technologies available for a road user charge incorporate various methods of collection. An on-board computer is required in all systems with the exception of direct odometer reading that integrates components,
stores data and calculates charges. Each system relies on more than one technology to locate vehicle position and record miles traveled. These options include GPS navigation systems, GIS digital data maps, odometer feeds and dead reckoning systems. Finally each system requires the means to transfer collected data to the storage center. This can be accomplished with, short range communication devices, GSM communications (satellite based cellular) and smart cards.

Presented below will be information that describes the technologies discussed above utilizing GPS/GIS, smart card, and odometer based technology. This section will also cover reliability issues, accuracy issues, and security measures that are important to the technology represented in the section. Below are some terms that will be repeated throughout this section:

On-board Unit: The OBU is a computer module that provides memory storage, computational power and a framework for integrating other on-board devices.

GPS: Global Positioning System is a satellite based network that determines position, velocity and time. GPS receivers can determine the location within the network, time of travel; distance traveled and speed of travel.

GIS: Geographic Information System is a digital road map that allows GPS receivers to translate latitude and longitude positions into an accurate location in the road network.

Odometer: The odometer can be utilized to measure the distance traveled as the primary source for recording or provide backup to the GPS system in case the signal is compromised.

Dead Reckoning: Is a device such as a gyroscope that can track the location of traveling vehicles for short distances in case the GPS signal is lost. This device is a suitable backup for the GPS system for short intervals.

Smart Cards: A card carrying device that stores data that can be removed from the OBU and taken to a convenience center where information can be uploaded to a collection center. (Sorensen and Taylor 2005)

Global Positioning System (GPS)

The goal with assessing a road user charge is to provide a fair and stable source of revenue that will support maintenance and construction. The system for charging road user fees must be reliable and accurate, so the consumer will have confidence in the system. The on-board GPS system accuracy depends upon the level of road user charges to be utilized. If the system will operate within a specific jurisdiction then current GPS and GIS technology is sufficient; if the system must distinguish between various road segments, then differential GPS corrections will be needed, and the digital road map of the network will have to be highly accurate. This will allow the proper charges to be distributed to vehicles traveling in close proximity to one another.

There are two important questions that need to be addressed for the purpose of GPS technology to play a viable role in road user charging. How accurate must GPS receivers perform too correctly locate a vehicle, and are these technologies currently available to meet the criteria? As mentioned above for the purpose of recording vehicle miles traveled in one jurisdiction GPS/GIS technology is an adequate system to be utilized. If the determination of charges will be assessed by a specific road or multiple jurisdictions, then the system must meet a higher level of accuracy then a standard GPS receiver.

For this determination differential positioning (DGPS) will be necessary to remove the effects of atmospheric errors, timing errors, and satellite orbit errors by providing sufficient accuracy to the system. Researches in a University of Minnesota study (Cheng 2004), that tested GPS receivers for their specific use in a road user fee program, revealed that a Differential Geographic Positioning System will be accurate for the purpose of a road user charging program. The test utilized GPS receivers available on today’s market, a Trimble-Ag 132($5,000), CSI-GBX 12R ($850)
and DGPS-212 ($500) receiver. The Trimble-Ag 132 (see below) outperformed the other units in the test, with an accuracy of 997 measurements out of 1000 being within 8 inches of the target, while the accuracy of the other two receivers tested were 27 feet and 36 feet respectively of the target. The Trimble-Ag 132 is able to distinguish between roads that are separated by only 6 feet, which is important if you have a road that intersects or runs parallel to an existing system. At a price tag of $5000 dollars per unit, a large demand for this type of unit to be mass produced would drop the price significantly. This type of technology would be best suited for installation by automobile manufacturers, to defer the cost of retrofitting each vehicle. The automobile manufacturer will then be responsible for installation of the unit and also for the price of the GPS system, passing this cost on to the consumer. (PIC)

In deciding how to implement the technology and infrastructure that will be used for a HUF we must take in account the implementation for the collection method. For this paper we will not use specifics for the state of Virginia. Instead this section will utilize results from studies by the Oregon Department of Transportation, the University of Iowa and other pertinent sources of information as it pertains to a HUF. This will give us an idea of the amount of time it could take for implementation.

For the Oregon’s Mileage Fee Concept and Road User Fee Pilot Program (also known as the Oregon Study) the Road User Fee Task Force (RUFTF) was allotted eight years to design and implement a new revenue collection system to take the place of fuel taxes. The Oregon RUFTF looked at a six year phase-in for the implementation of a system that worked with GPS. With the high cost of retrofitting existing vehicles with HUF equipment, it is likely that such a program would need to be phased in over time, similar to how the Oregon RUFTF utilized a phased implementation. New cars could be purchased with the required equipment already installed and would then be subject to a HUF, whereas older cars could continue to pay traditional fuel taxes until they are no longer in service or are retrofit. This phase in period, during which two revenue systems would need to be operated in parallel, would likely last around 20 years. (Whitty, 2007)

There are a few ways in which the government could collect the fees associated with a HUF. We can use the same method that was used in the Oregon Study. This was done tracking the miles of vehicles using latitude and longitude location points. The GPS system will also record the location of the vehicle. The transfer of the information from GPS to a server or fee collection center could be done using cellular connections and the proper fees would be calculated for that particular vehicle. In the Oregon Pilot Program, the on board diagnostic system and GPS worked together to collect and record the data from the vehicles.

Federal and state motor fuel excise taxes are collected at a relatively small number of fuel distributors within each state, which greatly simplifies the collections process. In contrast, a HUF could be collected at retail fueling stations (as in the Oregon pilot program) or alternatively from each individual user (as envisioned in the University of Iowa study). Although there are strategies for accomplishing these tasks, either of these scenarios would significantly increase the administrative burden of revenue collection.

A typical scenario involves setting up a monthly billing cycle. In this scenario, the user is charged on a monthly basis based upon the vehicle miles traveled for the previous month. A billing statement would then be sent to the user and the user would have the option of paying by cash, credit card, or check, however cash would only be accepted at collection centers with walk-in service. The cost for maintaining a monthly
billing system like this would include printing and postage fees as well as staff to handle the remittance of payments. Some electronic toll collection agencies offer users incentives to accept less frequent (i.e. quarterly) billing or paperless billing via e-mail. These measures could be implemented in order to reduce administrative costs. (Bertini 2002)

A HUF would require a significant social investment. The required onboard equipment would cost approximately $100 on average per vehicle, and there would need to be an additional investment in the information systems required to collect and distribute revenues. Installation of this equipment would cost about $250 per vehicle and to retrofit existing vehicles would cost an additional $200 per vehicle. (Zhang, 2007) Once this initial investment is made automation should make it possible to operate with a high level of cost-efficiency. (Whitty, 2007)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Hardware</th>
<th>Approximate Per Unit Hardware $</th>
<th>Cost Category</th>
<th>Approximate Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Acquiring OR-VMT</td>
<td>Getting Data Off Vehicle</td>
</tr>
<tr>
<td>Center Scenario</td>
<td>Integrated GPS/GIS/RF Unit</td>
<td>$500</td>
<td>Initial Cost</td>
<td>$1.5 B</td>
</tr>
<tr>
<td>GPS&amp;RF-AVI Option</td>
<td>RF Readers at Service Stations</td>
<td>$2,500</td>
<td>Var. Cost/Yr</td>
<td>New/Repl./Maint.</td>
</tr>
<tr>
<td>DMV Scenario</td>
<td>Integrated GPS/GIS/RF Unit</td>
<td>$500</td>
<td>Initial Cost</td>
<td>$1.5 B</td>
</tr>
</tbody>
</table>
|                      | RF Readers at DMV Offices                    |                                 | Var. Cost/Yr   | New/Repl./Maint.       | Repl./Maint.  | Software *
|                      |                                               |                                 |               |                        |               | Labor+Maint+Lic |
| Actual VMT @ Pump    | Integrated GPS/GIS/RF Unit                   | $500                            | Initial Cost   | $1.5 B                 | $70 M         | Software *  
| with Credit/Swit     | Dispensers - RF (New/Retrofit)              | $7,500                          | Var. Cost/Yr   | New/Repl./Maint.       | Repl./Maint.  | Maint+Licenses |
| ch GPS&RF-AVI Option | POS system (1/2 need)                        | $10,000                         |               |                        |               | Maint+Licences |
The level of accuracy desired is an issue that will have to be taken into consideration when balancing the system cost utilizing GPS technology. Road user charging on specific segments requires a system that will meet a higher standard of accuracy than established by standard positioning. The GPS digital map techniques need to be applied utilizing very close tolerances because many roads in urban and suburban centers are very tightly spaced.

Any GPS with low accuracies will increase the possibility for inaccurate road charges. To improve on this accuracy differential GPS will be utilized to correct for atmospheric errors, severe terrain, and multipath errors, while improving the level of confidence for the system. The utilization of DGPS requires another receiver at a fixed location nearby. The observations made by the stationery receiver are utilized to correct the measurements recorded by the moving units, producing accuracies of 3 feet or less. Differential GPS is a method that allows the user to obtain very high accuracies by utilizing a local reference station to augment the information that is available from the satellites, thus improving the integrity of the system by identifying errors.

To correctly match a given geographic location a complete digital road map will be required. A geographic information system integrates hardware, software and data for recording, analyzing and displaying all forms of geographic information. The geographic information system is a computer based tool that utilizes mapping and analysis techniques that links topographic and demographic resources. The topological structure of the GIS data base defines the location and relationship of highways, streets, and other features necessary for locating specific roads traveled for HUF. GIS can be merged with other data sources to create maps and conduct analysis. The two limitations to GIS road files for use in a user fee system is that some locations may yet to be included in the road files and according to a Minnesota research study (Cheng 2004) current commercial maps are unable to provide accuracies of 131 feet or less on a consistent basis. These limitations can be overcome with the advancement of updating of digital maps and further technological advances.

When signals become blocked by driving through tunnels, heavy tree canopies or roads that have not been included in GIS road files. The most accurate way to maintain distance and direction is through a DR (dead reckoning) system that will improve system performance. Dead reckoning is a backup feature that allows a navigation system to estimate your location if the signal is lost from the GPS satellites. Two systems that can be used to measure speed and direction when the signal is lost are accelerometers to sense changes in the vehicles speed and direction plus sensors that measure the distance covered by the vehicles wheels which will be needed for the HUF charge.

The protection against tampering and defrauding is fairly straightforward with the many security measures that are available with current technology. A few security measures are mentioned here. Protecting the collection of data with the on-board GPS system can be accomplished by requiring each vehicle to be given a unique non-forgable identifier that can be matched to the vehicle registration. The GPS unit shall be designed and packaged to prevent any tampering that would result in the loss of secure information and to detect any purposeful disablement of GPS signal reception by relaying this information to the collection center. Finally, the GPS system should detect any discrepancies between reported GPS data and independent odometer.

**Smart Card**

A smart card is any pocket sized plastic card that contains embedded integrated circuits that can track and store monetary values, and other data necessary for management applications. The term smart card in the transportation industry refers to an ISO-card that contains a microprocessor. These cards are machine readable, similar to magnetic stripe cards, while there functions are multi application data and storage retrieval. Because of the data storage and processing capabilities smart cards can
function across various transportation applications through their system compatibility. The smart card is flexible and convenient method interface between the computer on-board unit and the collection center that requires no infrastructure at fuel stations.

For the purpose of road user charges a typical contact based card system will be sufficient. The smart card will allow users to store charges in the on-board computer to be uploaded to the collection center at the specified time. The on-board computer can update any necessary information from the collection center, the on-board computer is typically used to store data and calculate charges, though it also can provide the framework for integrating other on-board technologies. The smart card will remain in the vehicle, while the on-board computer continually transfers data based on road use. The vehicles owner will be responsible for taking the card to a convenience store or service center to download the data to a card reader. If a GPS receiver is added to this type of system, a GIS file that contains data boundaries of counties or states to determine the jurisdiction that the vehicle has traveled will provide the means for zone charging. The collection center can send updates to the GIS files that are stored in the vehicles on-board computer as necessary.

Once the data is uploaded and verified by jurisdiction if necessary, the data will be removed from the system. All data flowing in both directions will be encrypted to prevent tampering and other security problems. The system will have internal tests built into the system to recognize any form of mechanical problems or attempts to breach the system. This type of system allows the user to transfer the minimum amount of data necessary for a road user charge so privacy issues will be of little concern. With this particular system the user can have the option of receiving a monthly bill similar to the system utilized by utilities or automatic billing from a credit/debit card.

Smart card technology has the potential for playing a role in a statewide VMT fee system, either as a permanent solution or during a transition phase (Kuhn 2002). Over a billion smart cards are already in use, primarily in Europe for their truck VMT tolling operations. According to Laura Taylor, the founder of Relevant Technologies, a provider of original information security content, research advisory services, and best practice IT management consulting services, there are a few things that should considered before implementing smart card use. This will ultimately have an impact on how long it takes to get the system running.

- Applications supported
- Storage capabilities
- Standards supported
- Processor Support
- Programming Capabilities

There is not much information on the use of smart card implementation as it pertains to HUF. This technology is currently being used in many applications. Some of these applications include mobile communications, retail, healthcare and for ID verification. One example of such an implementation can be seen by the U.S. Department of Defense (DoD). Smart Cards help eliminate standing in line, filling out forms and other processing chores, according to defense officials. Instead of moving service members from one station to the next, a simple swipe of the card provides all the necessary information. Flight manifests and deployment processing are completed in minutes rather than hours. Using the same scenario used by the DoD, it is presumed that the first year of implementation for a HUF system would be devoted to developing software and obtaining card stock and hardware. During the second year, hardware could be installed at gas stations and other locations were information exchange can take place. As the equipment is installed, local officials could then begin issuing Smart Cards and installing them in vehicles.

In order to collect the fees associated with a HUF using a smart card, the information must be taken from the card. Communication via a smart card is done using a reader that closely resembles the credit card readers found in nearly all businesses. Normally, the smart card occupies a slot in the vehicle’s dash panel. The on-board computer continuously updates the
smart card regarding total user charges owed to each state or other jurisdiction that may be defined by a polygon system. Data is transferred to the smart card in units of dollars. Before storing the data, the on-board computer will have (1) measured the distance traveled within each polygon, (2) applied the appropriate per-mile user charge as established by the applicable jurisdiction, and (3) calculated the user charges owed to each jurisdiction. Thus, the vehicle operator can remove the smart card at any time and insert into a reader to transmit the charges due to the fee collection center. (Kim, 2002)

A rate schedule downloaded from the collection center and stored in the on-board computer enables a user fee charge to be computed for each jurisdiction using the incoming HUF information. While the vehicle is in use, a smart card is connected to the vehicle’s on-board computer and is constantly updated with road user charge information. When a user wishes to upload his or her road use information, the person removes the card from the vehicle’s dash panel and inserts it into an upload station. These stations will resemble a credit card reading device and will be located in numerous convenience stores and other businesses or even in a person’s home. In time, refueling facilities may be equipped to allow a direct data transfer between a vehicle and the refueling apparatus. During the uploading process, the smart card authenticates the user, uploads the total charges accrued during the reporting interval, and then anonymously uploads the road use information needed for the apportionment of these charges among jurisdictions. When the collection center identifies the user, it checks for fraudulent behavior or malfunctions. If there is a problem, the smart card is notified to prompt the user to go to a service center, and the system flags that particular vehicle. During this communication, the collection center updates the vehicle’s rate schedule through the smart card if the stored schedule is not the current edition.

Once the collection center anonymously receives the information on how much of the mileage occurred in which jurisdictions, the center correctly apportions the funds to the appropriate jurisdictions in which travel has occurred. (Forkenbrock, 2003) The cost of monthly billing generation to an entire driving population could become significant. However, in some real world instances like the SmartTag electronic toll collection system in Virginia, to offset costs users are sent a free summary statement every three months. More frequent and detailed statements are available for extra cost, starting at $2.00 per month. This same method could be used to lower billing costs for a HUF.

To get an idea of the start up, operating and maintenance costs of a Smart Card implementation, I will use information supplied by a company called Gemalto. As mentioned earlier, there is not much information on this system as it pertains to a HUF so we must draw conclusions and make assumptions. This company is a digital security company that specializes in smart card technology. Below are estimates based on typical smart card implementations used by various companies and firms. This also includes system capital costs such as ID card design, issuance and management costs:

- Smart card – $8.00 each
- Smart card reader - $50.00 each
- Smart card server - $10,000 each
- Software development - $125,000
- System analyst training - $25,000
- General training $50,000
- Application support contract - $12,500
- Equipment replacement - $5,000
- General Maintenance - $10,000

This also includes system capital costs such as ID card design, issuance and management costs.

With a new approach to assessing road user charges the system in place must be free from attacks and resist any threat to the collected data. There are many threats that could disable and result in compromised vehicle data: (1) disabling the on-board system, (2) blocking the GPS signal, (3) override correct signals by false signals, (4) uploading false data, (5) attacks on
system access points, (6) hacking activities directed at storage locations (Forkenbrock 2002).

The system must be protected through three domains, while the information is stored in the on-board unit, uploading to the collection center and storage at the collection center. The on-board computer should be verified by a secure and independent vehicle odometer reading to the storage center at specific times, such as vehicle inspection. This will allow for the inspection of tampering to any system. The most effective means to protect data is by reducing the amount of sensitive data to be transmitted or stored.

The uploading of data will employ digital signals to verify all information transferred to the storage center. This will require encryption techniques be applied to each on-board computer. Each computer will be embedded with a private key and with a companion public key that is registered at the collection center. With these signatures the center can verify all reported data. All transfer devices are provided with diagnostic tests to diagnose any problem that should arise. Because the storage center will collect millions of dollars in VMT fees it must be protected from cyber terrorism and hacking attacks, which all government agencies face. This type of attack can be prevented by utilizing multiple data collection points throughout the state. The information gathered can be placed in a collocation facility that utilizes sophisticated firewalls for protection.

The choice of data transmission technology should reflect the needs of the program that is implemented. This can include operating ranges, data acquisition or transmission, communication requirements and life cycle costs. The two technologies that were consider in the Oregon study are cellular and direct link communications because of their proven results in other transportation applications. Cellular technology is a valid system to utilize despite the gaps that develop between both analog and digital coverage. This type of system is satellite based cellular and is the most costly, while being the most flexible. A GSM type of system allows real time communication anywhere within the system network.

Direct link technology (RF) is available in two forms for communication, passive and active. The passive devices receive their power from the reader, while being less expensive then active devices. These devices have lower strength limits for reading range and are prone to electrical interference. The active device can operate over ranges of up to 300 feet (Oregon Department of Transportation 2002) and is much more resistant to interference due a stronger signal. These devices are more expensive then the active device due to the complexity of their design. When this type of device is utilized the location of the tag/transponder is of critical importance to insure proper communication. One major drawback for this type of technology is the lack of a national standardization though there is an effort to standardize this type of technology for the intelligent transportation system.

There are three specific steps that should be considered when designing a secure system that will employ this type of technology: (a) Limit the amount of time and location data that is stored and reported in the vehicles on-board unit. (b) Encryption of sensitive data that is stored in the vehicles on-board unit utilizing a local embedded encryption key that cannot be revealed by the system to any outside source. (c) Encrypt all data transferred to the collection utilizing asymmetric encryption (Forkenbrock 2002). The collection centers public key should be utilized so that data can be decoded by the collection centers privately held key. The collection center should change the key on a weekly basis to minimize detection.

Odometer Based

Odometer technology relies on the mileage collection device of the vehicle that acquires information from a speed sensor on how many revolutions have occurred as the car travels. For the purpose of a HUF the odometer can be utilized for a direct reading that provides miles traveled or with the addition of short range radio frequency this type of system can
communicate miles traveled through wireless technology.

The technology required to operate this type of system if GPS will be added, is made up of a reliable odometer to measure the vehicle miles traveled and GPS receiver to determine the zone the vehicle is entering, including an on-board computer to integrate the GPS receiver and electronic feed to the vehicles odometer. The retrofitting will be accomplished by automobile manufactures to reduce the cost of implementation. The odometer/GPS device will collect and store vehicle miles traveled within the state of Virginia or the jurisdiction that is traveled in. A GPS receiver will provide basically a yes/no answer if the vehicle is traveling in a specific zone for assigning a user fee. The on-board unit will transfer stored data from mileage buckets that contain in-state and out-of-state miles traveled, each corresponding to a different charge category.

The on-board unit will communicate by short range radio frequency with wireless technology; transferring the billing data from the pump to radio receivers mounted at service stations. When vehicles that contain these on-board units purchase fuel at service locations the current mileage charge will be added to the fuel charge while the built in fuel tax will be deducted. The on-board units will include the vehicle identification number, odometer reading, the fuel grade, driving distance. There will be no point location data recorded and all communication will be short range. The evaluation and testing with this type of system indicates that a HUF based fee collected utilizing this type of technology is feasible based on results from the Oregon DOT study.

The time of implementation by use of an odometer depends on what type of system it will be used in conjunction with. According to the results of the Oregon Study, if the odometer is GPS based the implementation could take over 20 years due to fleet turnover. This is based on whether or not to retrofit existing vehicles. On the other hand if an odometer tag is used it could take less than 10 years. There are several ways in which the fee can be charged to the user. Data could be uploaded from the electronic odometer within the vehicle via radio frequency to a gasoline service station for purposes of calculating the fee based upon actual miles traveled. (Kim, 2004)

Retrieving information from an odometer manually requires minimal time for implementation. This information can be documented during vehicle safety inspections. In the state of Virginia it is required that most vehicles (with the exception of vehicles older than 25 years) have to be inspected for safety every year. These inspections look for safety violations such as brake condition, windshields and suspension. Also, some counties (mainly in Northern Virginia) require that vehicles pass an emissions inspection prior to the registration of that vehicle. This inspection must be conducted every year and can be done at emission stations like gas stations and repair shops. With this system and infrastructure already in place and it would be an ideal time to have the miles traveled recorded from the vehicles by an official who can input the information into a server or send it to a fee collection center.

The initial start up cost using an odometer method depends on the type of system in which it will be used. If this system is based on an electronic odometer in the form of GPS, current estimated cost would be about $500 installed per vehicle based on information from the Oregon Study. If the system is instead based on an electronic odometer in the form of an Odometer Tag, the current estimated cost would be about $125 installed per vehicle. (Kim, 2004) The cost of operation and maintenance will vary depending on what type of system is used with the odometer. This can be seen in the chart on the following page.
The upload of data from the on-board computer to the storage system must be maintained to preserve the overall integrity of the system. It is most likely the user will face at some point disruption in the signal, through equipment malfunction or physical obstructions. Tampering with the odometer is a Federal offense, under the Federal Truth Mileage Act, and information related to the odometer is required on the vehicle’s title or the Odometer disclosure statement. The odometer can be provided with a certificate of authentication when the yearly vehicle inspection is due.

A fully integrated odometer will be capable of providing the on-board computer with accurate VMT. Many of today’s vehicles are equipped with standardized communication protocol called SAE J1850 enabling all electronic modules to communicate with each other. The engine control unit counts all the pulses by tracking the overall distance the vehicle has traveled. If the odometer is compromised the value stored in the ECU will disagree. These discrepancies can be detected through the use of a diagnostic computer (Odometers 2008).

Policy Issues

The task of any government in introducing a new fee or tax system to fund a government activity will result in dealing with economic and public policy issues. Citizens of the United States are by and large opposed to any kind of charge and usually do not like taxes. Educating and effectively explaining the need for a change is crucial in gaining the public’s acceptance of a new system and if successful, will lead to a point when a state legislative body will move towards approving the new fee or tax system.

There are numerous policy issues surrounding the current transportation revenue system in the Commonwealth of Virginia. These same issues, along with additional and new issues, will need to be addressed if the Commonwealth of Virginia is to change to a HUF system. Issues such as equity and collection would need to be managed in order to ensure that the HUF is efficient and reasonable to all citizens of the Commonwealth of Virginia. Addressing the privacy concerns of the public and the political/public policy issues surrounding a HUF will be paramount in gaining the public and political acceptance necessary to implement a HUF. Coordinating between all groups involved, such as public officials, automobile manufacturers, the public and public policy advocates, will be the first step in ensuring that an effective HUF is in place.

Equity

Whenever there is a discussion of current or future road finance systems among policy officials, equity issues are usually brought to the forefront. The transition to a HUF system will require careful assessment and consideration of who benefits and who pays. These equity issues are typically raised in a variety of contexts. The more prevalent equity issues that are debated are equity between vehicle class, equity between income groups and geographic equity. These specific issues, which will be discussed further in the next section, will need to be addressed before an equitable, effective and efficient HUF system can be implemented.

When examining different road financing systems, many transportation analysts and experts believe that a HUF system has the potential to be one of the more equitable systems. A HUF has the advantage of being directly related to road usage. A HUF system would create a logical and transparent connection between those who pay for transportation improvements and those who use them.

Current technology has allowed a HUF system to be operated so that the fee can be varied to capture the necessary data equitably and justly from potential drivers. (Rufolo, Bertini & Kimpel, 2001, pp. 11-12) Unlike other road finance systems, a varied HUF system can equitably account for hybrid/alternative fuel vehicles and heavy vehicles that cause the greatest damage to a road system. From an economic efficiency standpoint, a variable rate HUF is appealing because it can closely approximate the true costs of travel on a per
vehicle basis imposed on society. (Rufolo, Bertini & Kimpel, 2001, pp. 11-12)

**Income Level**

One of the biggest challenges of implementing a HUF is the perception that lower income people would be charged proportionately higher fees than people that make more money. This is because a HUF, like many fees, does not take into account a user’s gross income when it is applied. Many experts argue that the burden of additional user fees are, in effect, a regressive form of taxation and most negatively affect those who least can afford them. In a HUF system, what income group would be affected the least/most by a mileage-based user charge would be very similar to the effects of the current gas tax system.

Some approaches that have been suggested to counter this perceived regressivity are providing income sensitive mechanisms on HUFs and fund public transportation to a higher degree when implementing HUFs to ensure that people affected by rising vehicle fees have viable transportation options. (Resource Systems Group, Inc., 2007, p. 3) Another option that the Commonwealth of Virginia can use to alleviate the issue of regressivity associated with a HUF are refunds through the state income tax. The Commonwealth of Virginia can determine an income level in which people who fall below this level would report their miles traveled on their state income tax return. This would allow the Commonwealth of Virginia the ability to refund a certain portion of the HUF that these people paid throughout that year. By incorporating this into the HUF scheme, the Commonwealth of Virginia would not incur any additional costs when creating the mileage based fee system. In addition, this would be immensely beneficial in gaining public acceptance into a HUF system from lower income people who may feel that this fee would adversely affect them. In contrast, it could decrease the level of acceptance among higher income people who could perceive this as an inequitable situation based on their higher socioeconomic status.

**Geographic Location**

**In-State vs. Out-of-State Drivers**

In a HUF system, how to impose fees on vehicle travel across state lines for in-state and out-of-state drivers would be one of the more substantial issues to resolve before implementation. Drivers from out-of-state could travel throughout the Commonwealth of Virginia and obtain gas from their own state, thus avoiding the HUF. This issue would also not be fair to in-state drivers who travel out of state but still would have to pay the HUF for these miles traveled.

Advancements in automatic vehicle identification (AVI) technologies are going to be essential in addressing this issue. AVI technology is point based and has the capability to collect and transmit information from a fixed location. (Rufolo, Bertini & Kimpel, 2001, p.39) The Commonwealth of Virginia can implement this technology at state border crossing points so that the information of the vehicles entering or leaving the state can be identified and recorded. One current system that could be analyzed that uses this type of technology is the London congestion charge system.

In 2003, London established a congestion charge zone in which any vehicle traveling into the zone would be charged a fee. Capita Group, the organization in charge of operating the scheme, captures the vehicle information by using closed-circuit television and automatic number plate recognition. This technology allows Capita Group to monitor and capture the information of all vehicles that enter the zone and to accurately send a bill to the driver. The Commonwealth of Virginia could incorporate this type of technology, although on a grander scale, to a HUF system.

Implementing a system such as the London congestion charge to capture in-state and out-of-state travel information would require additional time and money to have the necessary technology in place. The original set up costs for the London congestion charge was £161.7 million (approximately 241 million U.S. dollars). (BBC London, 2008, p. 3) Because of the larger area to cover, the Commonwealth of...
Virginia should expect costs upwards of $300 million to implement a similar system. Although the start up costs of introducing this type of system will have a high price tag, the system can be put into place in a relatively short amount of time. With the London congestion charge system, the Mayor of London approved the final form of the scheme in February of 2002 and the system was operational on February 17, 2003. (Transport for London, Background Information)

Rural Drivers vs. Urban Drivers
One fear that many have when assessing the possibility of using a HUF system is that rural drivers will be adversely affected compared to urban drivers. It is usually argued that in rural areas there are fewer or no public transportation alternatives which results in the need to own a vehicle to travel where needed. In addition, destinations for rural travelers are typically further apart which translates to higher vehicle miles traveled.

Research and studies have been recently completed that counters this argument. Oregon State University (OSU), in coordination with the Oregon Department of Transportation, conducted research into this issue. Their conclusions disputed the assumption that rural motorists drive significantly more miles than urban motorists. The OSU research revealed that while rural motorists may drive longer distances for some purposes, there is not more than a 10 percent differential between the overall rural driving compared with urban driving. (Whitty, 2007, pp. 62-63)

Although this study has refuted the issue that rural drivers would be adversely affected by a HUF, other results may show that rural drivers do travel more miles than urban drivers. To address this disparity, the Commonwealth of Virginia can create a mileage fee rate structure that would ensure a fair and equitable system for each driver. Specifically, the development of population based zones throughout the state with differential mileage fee rate structures could require that rural zones pay a lower fee in relation to urban zones. Adding this fee differential would place no extra costs in implementation and it would require only one additional step to the HUF system to accurately compute and collect the necessary vehicle information.

Vehicle Type

Vehicle Efficiency
In 2005, President George W. Bush signed new energy rules into law that would establish a renewable-fuel standard. This legislation, along with the Advanced Energy Initiative he announced in his 2006 State of the Union address, stresses the importance the federal government places on developing an alternative fuel source for our nation's automobiles. The law has provided for tax benefits for alternative fuel sources such as ethanol and bio-diesel and promoted research and development into other alternative fuel sources such as methanol and compressed natural gas. (Allen, 2006, p.1)

Another line of vehicles that are scheduled to be introduced to the American public in the near future are Plug-in Hybrid Electric Vehicles (PHEV). As of September 2008, PHEV passenger vehicles are not on the market for sale in the United States. Automakers, Toyota (Thomas, 2006), General Motors (General Motors, 2006), Ford (Woodall, 2007), California startups Fisker Automotive (Shirouzu & Buckman, 2008) and Aptera Motors (Aptera Motors, 2007), and Volkswagon (Thompson, 2008), have all announced their intentions to introduce PHEV passenger vehicles and have them enter the marketplace over the next few years. The technical advancements of using
alternative fuel sources along with the introduction of non-liquid fuel vehicles will result in a significant amount of these types of vehicles driving on the roads in the future; which will raise the issue of how to capture the necessary information for the HUF system used.

Data collection for alternate fuel source vehicles would be no different than for gasoline operated automobiles in a HUF system. Automobiles that use an alternative fuel source would still be required to fill up at some type of fueling station. The issue of collection for automobiles that use an alternative fuel source would be at the pump. There are various options available for alternate fuel, which could create an issue; fueling stations would need to be capable of dispensing and collecting each of the different alternative liquid fuels. New technology would be necessary to dispense and collect the various alternative liquid fuels, which would result in needing a “hybrid” pump system, capable of capturing the vehicle miles traveled data from all of the alternative liquid fuels. This would impose an extra expense on stores that would dispense the alternative fuels because they would most likely need to upgrade their pump system. This necessity could cause a backlash by fueling stations that might not choose to upgrade their pump systems.

In a HUF system, there are generally three options for which PHEV passenger vehicles could pay. The first option involves uploading the vehicle miles traveled data wirelessly through electric utility meters. This data then is transferred over and billed through the drivers’ monthly electric bill. This upload could take place near any electric meter, and the vehicle identification number would direct the vehicle miles traveled fee to the proper account for billing. Since this option would use an existing billing system, a cost savings would be created by choosing this type of vehicle miles traveled fee system. This option offers convenience for the driver, as the driver would pay the electric bill as before with additional HUF charges, as opposed to handling a separate invoice. (Whitty, 2007, pp. 65-66)

The second option would involve cellular uploads of the vehicle miles traveled data to centralized data and billing centers. This type of collection would be much more feasible when starting with a small population of vehicles. For widespread implementation, this type of collection would require substantial capital and operating costs. This type of collection would never be practical when compared to a system that attaches to an already existing billing or taxing system. (Whitty, 2007, p. 66)

The third option would upload the vehicle miles traveled data and collect the fee at the time of vehicle registration. The collection-at-registration would pose challenges in widespread implementation in the Commonwealth of Virginia because currently drivers are only required to report the odometer reading when they register their automobile once, when the driver purchases the automobile. In order for the registration system to be used for the collection of the vehicle miles traveled data; it would necessitate a change in the registration laws for automobiles in the Commonwealth of Virginia. (Whitty, 2007, p. 66)

**Sale of Alternative Fuel Vehicles**

Critics of a HUF system assert the possibility that a HUF could be a disincentive for individuals to purchase fuel-efficient vehicles. This issue can be looked at by different viewpoints. Drivers who operate fuel efficient vehicles question fairness of a HUF based on the fact that they operate vehicles that place a lesser burden on the environment. They argue that they should suffer a lesser penalty than those drivers operating vehicles that make a larger impact. This may seem valid if you view this issue from an environmental aspect only. When you also consider that each vehicle driver requires the road system to be available when they pull out on to it, then an associated responsibility to pay for the system emerges and the point loses merit.

To have an equitable HUF system each vehicle should pay a fee to use the road system. When the implementation of different fees for different vehicles is used in the structure of a
HUF system, transportation officials and local decision makers could implement a structure encouraging the purchase and use of fuel efficient vehicles. The HUF system could charge a lower per-mile rate for fuel efficient vehicles compared to a higher rate for vehicles that are not as fuel efficient. The HUF system could determine which vehicles are fuel efficient by assigning different categories based on fuel efficiency and/or level of criterion emissions as defined by the U.S. Environmental Protection Agency. The Commonwealth of Virginia could then assign a different per-mile rate to each of the vehicle categories. By assigning different fees, the Commonwealth of Virginia would still have a system in place that would encourage the purchase of fuel efficient vehicles and it would add no extra cost or time constraints on the implementation of a HUF system.

**Vehicle Weight**

A vehicle mile based fee system can more accurately assess and calculate the costs associated with the damages that heavier vehicles impose. The FHWA in its 1997 research, *Federal Highway Cost Allocation Study*, concluded that heavy vehicles underpay for their road use because the damage they do to roads is much greater than the amount paid in fuel taxes. The study especially found this to be true when comparing the road damage cause by lighter vehicles. In *Road Work: A New Highway Pricing and Investment Policy*, the authors indicated that for each mile traveled, an 11,793-kilogram (26,000-pound), single-unit, two-axle delivery truck may impose pavement costs 1,000 times higher than caused by an automobile. (Forkenbrock & Hanley, 2006, p. 3)

Unlike the gas tax, a HUF system can be structured to accurately reflect the road damage caused by heavier vehicles. The HUF system can assess higher fees on heavier vehicles by using a multiplier based on certain criteria such as: weight class or number of axles on the vehicle. The Commonwealth of Virginia could incorporate the same weight classes that the State of Oregon used in their mileage fee study. In Oregon, it was decided that automobile weight differences would be separated into three classes: light (less than 8,001 pounds), medium (8,001 to 26,000 pounds) and heavy (over 26,000 pounds). (Rufolo, Bertini & Kimpel, p. 17) The HUF system would then be structured to charge the base fee for light vehicles, impose a fee two times the base fee for medium weight vehicles and then a fee three times the base fee for the heaviest vehicle.

Several European countries have successfully implemented a mileage-based fee system for heavy goods vehicles (HGV). The foundation of these road user charges, more commonly known as Lorry Road User Charging (LRUC), could be used the same way in a HUF system. The Swiss Custom Authority (OZD), in Switzerland, started operating a heavy vehicle distance based charging system on January 1, 2001. The OZD required every truck in Switzerland to be equipped with a GPS based onboard unit that could be used to collect data. The principles of the scheme are that the vehicle is charged by distance traveled (in Switzerland) and is charged based on the maximum gross laden weight of the total vehicle train (including any trailers being pulled on the journey in question), not actual weight. The rates vary from 1.42 to 2.00 Rappen per km per tonne of lorry weight, depending on the lorry’s emission class. Germany, in response to the negative impact and growth of freight transport on German motorways, developed a mileage based pricing scheme for vehicles over 12 tons. All German freight trucks are equipped with on-board units which contain satellite-positioning equipment that records distances traveled on German motorways and then calculates the associated charge. The current rate that Germany has established ranges from €0.09 to €0.14 per km. With the success of these LRUC and the positive public acceptance, a framework has been put into place to introduce a common European service for road user charges. Efforts are currently ongoing or underway to define this service so that it allows for interoperability between different types of road user charging systems and could be in place as early as 2009. (HM Treasury & The Department for Transport, 2004, pp.21-24)
Privacy

With privacy being such a major concern for the implementation of a HUF system, any proposed HUF system will have to take steps to address privacy as a critical issue. The majority of citizens do not want their movements tracked and their driving history available to anyone, especially the government. While this feeling is certainly a reality, most people already allow access to their personal data to the private sector on a regular basis in the form of insurance inquiries, credit card transactions and in the most common form, the use of cellular phones. Many would argue however, that this information is simply being passed to private companies and not to the government, and the information that is given is not used for purposes other than the private company’s use. In a study done by the Dieringer Research Group entitled Mileage Based User Fee Public Opinion Study, it was found that the overall feeling of the general public was that they simply did not want a big brother concept. The general public did not want personal information passed onto the government because they feared what the government may do with it. The public’s general fear is that the government will capture private transportation movements and then use the data for some purpose other than what the data was captured for to begin with. While these concerns are certainly important, it was proven in the Oregon Study that privacy could be protected. Many users who originally felt unease with the concept changed their opinion by the end of the study. Regardless of how thorough a HUF system is at protecting privacy, there will always be those citizens that express opposition. While their opinions are valid, they should not influence whether a HUF system proceeds or not.

Addressing GPS privacy concerns

GPS technology, as explained earlier in this report, provides great opportunities for an effective and efficient HUF system. Although the general impression of GPS by the general public is that it can be used to track the exact location of your movements, in reality it can be tailored to collect only the information needed. When gathering data only, the receiver only collects the vehicle miles traveled and not where the vehicle actually is or has been. By customizing this technology, it will alleviate the fear of having a driving history available to the government, which is a major concern for citizens. While GPS technology could be considered one of the best means of capturing data needed to implement a HUF system, it also comes with a higher cost than other options. Although GPS systems have decreased in cost over the years, the cost to install GPS transformers on vehicles will be substantial. Many newer vehicles have GPS capability; however the time needed to turn over vehicles is significant. How long would the transition period be? A report entitled Issues in road pricing for networks by Robert W. Poole, Jr. and Adrian Moore indicates that 95% of the US vehicle fleet turns over in 20 years. And there are some indications that the life of a vehicle is actually getting longer, which might make the transition period lengthier. The transition period can only begin once there is agreement (federal, state and auto industry) that after a certain date, all new vehicles that use public roads will come equipped with a GPS that is suitable for HUF charging. If we started today to build the case for such a decision, it might take five years to reach enough of a consensus for action to be taken. Additionally, assuming the auto industry needed another five years to design and integrate the GPS into every make and model, the beginning of such a transition would appear to be a minimum of 10 years away. Add this to what Poole and Moore estimate, a 20 year turn over time period for the U.S. vehicle fleet, and a universal HUF charging system would exist 30 years from now. GPS technology is a double edge sword. While privacy can be obtained by collecting data only, the opportunity for a privacy breech is certainly higher when using GPS. This along with the lengthy transition period to implement GPS technology in each vehicle makes using GPS technology in a HUF system, though extremely beneficial, potentially risky as well as costly.

Addressing Smart Card privacy concerns

Another option that could be used to collect the vehicle miles traveled data in a HUF system is
the Smart Card concept. The Smart Card concept can be used either independently by each driver or in combination with GPS. Dependent on which way this technology is used will determine the privacy risks associated with a Smart Card system. A HUF system that uses Smart Card independently by each driver will reduce the issues surrounding privacy. In contrast, a HUF system that uses Smart Card in combination with GPS will be faced with the same privacy issues that challenge a GPS system which is a vehicle’s movements could be tracked and monitored.

An extra security measure that can be taken to provide additional protection of driver privacy would be to encrypt the computer chips that are installed in Smart Card technology.

There are minimal costs to drivers in Smart Card technology as each driver would need to purchase a card. The greatest concern over added costs and time with using Smart Card technology on a HUF system concerns the implementation of the technology to read the data. Having every business who sells gas to switch over to a pump system that has the Smart Card technology would take considerable time and money, but there would be an incentive for the businesses to do so; they would face the reality of going out of business if they did not switch. A benefit to using the Smart Card system is that a third party (company or organization) could operate the technology and complete the billing therefore reducing the fear that the government is watching the consumer’s movement. Although this would reduce privacy concerns, there would be an added cost of hiring a third party to operate technology, billing and collection system.

Addressing Odometer-Based privacy concerns

Reading and reporting the mileage straight from the odometer is another means that a HUF system could use to collect the necessary vehicle miles traveled from each driver. Reading the mileage from the odometer can be completed either by each individual driver at a determined time, at an automobile’s state vehicle inspection or at the time the driver purchases and registers the automobile. Using this method of collecting the vehicle miles traveled data in a HUF system would create an optimal solution to the public’s privacy concerns and issues. In addition, this method is immensely beneficial because all vehicles come with an odometer installed thereby eliminating any added cost or time during implementation of a HUF system.

While this option eliminates the privacy concern, it is not a favorable option. This type of collection method would create a system where the vehicle miles traveled data is collected either once a year or only a few times a year. Most citizens would prefer to pay a fee incrementally rather than a lump sum at one time. Another issue with this concept is the fact that there is a greater opportunity for the odometer to be tampered with. While an odometer reading is simple and can be done with very little cost, it has been determined by most analysts and experts that it is not the best option for a HUF system.

Mitigating Issues and Educating the Public

Addressing equity and privacy issues are both major factors in the development of a HUF system. Every previous pilot project, many of which are referenced in this report, has stressed the importance of concentrating on both of these issues. The general public’s apprehension to such an endeavor is to be expected, however there are things that can be done to help ease the resistance.

While both equity and privacy are crucial issues, if given the proper attention, they can be managed. Even with the most up to date technology, there is a real need to share information with the public to ensure that equity and privacy issues are a priority. A strong public relations campaign can be a very helpful way to accomplish this. This was proven to be an integral part of the Oregon study. As in the Oregon study, it will be important for Virginia to hold several public hearings, conferences and symposiums on the HUF concept in order to hear the concerns of citizens across the Commonwealth of Virginia. There will be a need to focus on the technology that is available for the implementation of a HUF system and how
the technology works. In these hearings it should be revealed how the technology can be used to capture the necessary collection data without compromising privacy and remain equitable to all drivers. The print, broadcast, and electronic media is another important part of the effective communications plan. By using each of these resources, the Commonwealth of Virginia can educate a great deal of people in a short amount of time. As with any controversial subject there will likely be a great deal of negativity in the media about the HUF concept. It will be important to establish a positive media campaign very early in the process to offset negative publicity. To ensure that an equitable and efficient HUF system is in place, the Commonwealth of Virginia would need to process the public’s concerns and question so that their issues and fears are sufficiently addressed.

**Possible Pilot Programs for Virginia**

Before a HUF can be deemed feasible in Virginia, a pilot program should be completed to test the preferred technical option in a real-world environment. A pilot program will collect Virginia-specific data and help to flush out any unforeseen issues before implementation. If the results of the pilot program are favorable, they should be well publicized. This will aid the public outreach and education process by helping to answer questions and ease public concerns about the HUF in Virginia. It is important that Virginia heeds the lessons learned from previous and ongoing HUF studies so that it can expand upon their objectives and tweak them to fit Virginia’s unique circumstances. By performing its own comprehensive pilot program, Virginia will become a leader in HUF research and be relied upon for knowledge, guidance and experience if and when a HUF program is sought after on the regional or national level.

A pilot program could be implemented in Virginia with technology that is currently available and was previously discussed in this report. The first order of business would be to establish a task force like the one formed in Oregon to help determine the goals that need to be met and criteria that need to be evaluated in order for the pilot program to be considered successful. Next, basic budgets and timelines should be estimated for each phase of the pilot. These figures could be based on cost and schedule information from previous and ongoing HUF studies and adjusted to fit the specific needs of Virginia’s program.

Virginia could choose between a variety of different methods to institute a HUF since any combination of GPS, Smart Card and Odometer based technologies could be tested. In the Oregon pilot study, a GPS enhanced “Odometer/Pump read” method was selected. Transportation officials wanted to minimize changes to the driver by allowing them to continue paying for fuel at the “point of sale”. They also wanted a system that could “mesh” in with the traditional gas tax method to provide for a phase in period and to accommodate all vehicles including older vehicles and out-of-state drivers. Integration with the current fuel tax system should also be considered in a Virginia study. Coordination with the federal government will be paramount as well because it is not likely that a HUF will succeed without federal support. Virginia should seek financial aid from the federal government to help offset expensive initial costs in return for federal oversight and input.

There are five technical options that a pilot program could be based on: Odometer Manual Read, Odometer-Pump Based, Odometer-Pump Based with GPS, Smart Card Stand Alone and Smart Card with GPS. Virginia could consider researching one or all options for its HUF pilot program, and this research could be conducted individually or concurrently at different locations throughout the state.

The optimal number of participants for a pilot study focused on any of the five proposed options would be between 200 and 300 drivers and each participant would need to install required electronic equipment on their vehicles and purchase fuel at the participating gas stations as applicable. A control study could also be run at the Virginia Tech Transportation...
Institute (VTTI) to make sure that the technology for each option was operating as planned. The Institute has twenty-five instrumented vehicles that can be quickly tailored to the specifications of a project and a 2.2 mile closed roadway for testing. The pilot study itself should take place in a small to mid-sized metropolitan area such as Lynchburg, Staunton, Blacksburg or Charlottesville because participants would be familiar with the area and selected fueling stations. A city or town close to a state border would be ideal for testing either the Smart Card or Odometer-Pump Based technology that is enhanced with GPS because it would allow the system to test its ability to differentiate between miles traveled in and out of state.

Cost for the five options vary and increase as the technologies become more sophisticated. Although the cheapest option to study, the Odometer Manual Read presents other challenges. Virginia would have to involve the state police and auto repair shops to test the option’s feasibility during state inspections, and would have to involve the Department of Motor Vehicles to test the option’s feasibility during the vehicle registration process. A pilot program focused solely on the Odometer Manual Read option could begin in less than a year and cost the state little to nothing for additional equipment and approximately $500 per participant to administer.

The remaining four options would require the state of Virginia to purchase on-board computers for participants’ vehicles at a rate of approximately $250 per unit and require additional equipment be installed on each gas pump for $300. Options that include GPS enhancements would require GPS receivers for each participant at a cost of approximately $125 per unit. Smart Card options would require the purchase of an $8 Smart Card per participant. The administration costs for each program can be estimated at an average of $25,000 per month from conception to conclusion. These options would each take between one and three years to set up depending on their varying degrees of technical complexity, and would take between six months and one year to study. See the chart on the next page for a detailed list of the costs for each pilot program option.
## Estimated Costs for Pilot Study Options in Virginia

<table>
<thead>
<tr>
<th>Study Option</th>
<th>Hardware Required</th>
<th>No. of Units</th>
<th>Cost (each)</th>
<th>Months to Complete</th>
<th>Admin Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odometer - Manual Read</td>
<td>Odometer</td>
<td>200</td>
<td>$0</td>
<td>18</td>
<td>$100,000</td>
<td>$100,000</td>
</tr>
<tr>
<td>Odometer – Pump Based</td>
<td>On-Board Computer</td>
<td>200</td>
<td>$250</td>
<td>42</td>
<td>$1,050,000</td>
<td>$1,101,500</td>
</tr>
<tr>
<td></td>
<td>Pump Wireless Reader</td>
<td>5</td>
<td>$300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Odometer - Pump Based with GPS</td>
<td>On-Board Computer</td>
<td>200</td>
<td>$250</td>
<td>48</td>
<td>$1,200,000</td>
<td>$1,276,500</td>
</tr>
<tr>
<td></td>
<td>Pump Wireless Reader</td>
<td>5</td>
<td>$300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GPS</td>
<td>200</td>
<td>$125</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smart Card Stand Alone</td>
<td>On-Board Computer</td>
<td>200</td>
<td>$250</td>
<td>42</td>
<td>$1,050,000</td>
<td>$1,103,100</td>
</tr>
<tr>
<td></td>
<td>Pump Wireless Reader</td>
<td>5</td>
<td>$300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Smart Card</td>
<td>200</td>
<td>$8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smart Card with GPS</td>
<td>On-Board Computer</td>
<td>200</td>
<td>$250</td>
<td>48</td>
<td>$1,200,000</td>
<td>$1,278,100</td>
</tr>
<tr>
<td></td>
<td>Pump Wireless Reader</td>
<td>5</td>
<td>$300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Smart Card</td>
<td>200</td>
<td>$125</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GPS</td>
<td>200</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusion

Virginia’s highway and overall transportation system is vast and in need of proper maintenance and management. A significant amount of pavement on its 57k miles of primary, secondary, and interstate highways are in need of some repair. The same can be said for a good portion of the state’s 12k plus bridges.

For well over three-quarters of a century the gas tax provided Virginia a stable stream of revenue used to maintain the state’s transportation infrastructure. However, for a variety of different reasons ranging from a reduction in how much Virginians are driving to the advent of hybrid automobiles, revenue generated by the gas tax has been eroding right along with the state’s essential transportation system. State and federal transportation revenues are projected to decrease between $2.1 and $2.6 billion over the next six years. Virginia’s Secretary of Transportation Pierce R. Homer said at a Commonwealth Transportation Board meeting on Oct. 15 of this year: “We must make fundamental structural changes to our transportation administration, services, programs and projects to address this long-term change to our revenue base”. Homer further added: “The weak economy and reduced state and federal transportation revenues require that the existing transportation budgets and the Board’s Six-Year Improvement Program be further reduced.”

What this research paper sought out to do was shed light on a viable and real alternative to the gas tax that will be not only more reflective on how users use the highway but also be more adaptive to emerging technology and the market forces that cause fluctuations in how much revenue the gas tax can generate. It appears that as things stand today, Virginia’s gas tax is not going to adequately be able to fund the state's transportation system. A VMT user fee on the other hand, if implemented correctly, would be able to be much more resistant to the conditions that have caused the gas tax to lose its revenue.

Perhaps one of the most attractive aspects of a HUF is that it is a funding mechanism that is feasible and can be implemented on both a short term and long term basis as an alternative for the gas tax. Virginia can design a pilot study to further test the feasibility of a HUF prior to implementation. A pilot study can reveal deficiencies in the design of a proposed HUF and its framework and these can then be addressed before time and resources are expended on large scale studies. At this time a GPS based on board computer seems to be the technology that is available and currently in the forefront with regards to data collection and enforcement of a HUF. Additionally, more and more automobiles are coming equipped with GPS already installed as a standard feature. For those owners of automobiles that would need to be retrofitted; a unit can be purchased at a price that will be discounted if the state purchases its units in large quantities.

Many questions and implications have arisen as a result of researching the feasibility of a HUF as a replacement for the gas tax. For example, many questions have surfaced concerning the equity of such a fee on the different types of automobiles and their owners. Privacy concerns with regards to how and what kind of data is collected is an issue. Will drivers of hybrids lose the advantage of owning a fuel efficient vehicle? In light of all these issues raised, it has been determined that public acceptance and education will be essential to the success of a HUF. A clear and concise description of the program will be paramount to avoiding any confusion and misinterpretations.

The revenue generating prospects of Virginia’s gas tax do not seem to be very good. On Feb. 15 of this year, the Department of Taxation for Virginia notified the Commonwealth Transportation Board that transportation revenue collections for the department will decline by $722 million over the next six years. That means the money sent to the nine VDOT districts that encompass the state will decline by 44% on average during that six year span. A HUF can plug this hole that will be created by
the gas tax by directly charging drivers based on their road usage, not gas usage. It is clear that Virginia’s government can pretend to accurately predict the overall economy and gas price levels (two important determinates in how much revenue the gas price generates) as easy as they can anticipate how miles Virginias will drive. With the HUF there is no real threat of a diminishing tax base – not the case with the gas tax.

As with any new system there will be hurdles to get over and issues to be address. Questions and concerns ranging from feasibility to cost will have to be answered and addressed but the good news is that there are viable and real life solutions that are available now to deal with the majority of these issues. More importantly, in the not too distant future the shortfall of revenue caused by an inadequate gas tax will in one way or another force Virginia’s legislature to make some type of decision and take action to fix its transportation funding woes.

It is important that Virginia begin investigating a possible alternative to the gas tax sooner, rather than later. The handwriting is on the wall with regards to the transportation funding issues that the state will face in the very near future. This is compounded by the fact that the states aging transportation infrastructure is already in need of repair. The search for a alternative transportation revenue becomes more and more important as each day passes. Other states are aggressively looking into different funding mechanisms to raise transportation dollars and several of these states are looking towards some kind of fee based on road usage – similar to the HUF discussed in this report. Consequently, it is imperative that Virginia act now and begin its own research into a HUF so that it does not fall behind and become forced to follow the lead other states have taken. Virginia is a leader in the field of transportation, and the implementation of a HUF will help to keep it there for years to come.
References


Barge, Bill. (Spring 2002). *Smart Card Technology.*


Fuel economy, retrieved from www.fueleconomy.gov/feg/findacar.htm


The University of Iowa, Mileage-Based Road User Charge. *Study FAQ's.* Retrieved from http://www.roaduserstudy.org/faq.aspx


Analyzing the Feasibility of a Highway User Fee for the State of Virginia


Zhang, Lei. (2007). *Statewide Distance-Based User Charge: The Case of Oregon*. 