5-2015

A More Perfect User Fee: Examining the Viability of a Vehicle Miles Traveled Fee as an Alternative to the Gas Tax

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A MORE PERFECT USER FEE: EXAMINING THE VIABILITY OF A VEHICLE MILES TRAVELED FEE AS AN ALTERNATIVE TO THE GAS TAX

by

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A thesis proposal submitted in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE

in

Political Science

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UTAH STATE UNIVERSITY
Logan, Utah

Fall 2015

INTRODUCTION

The United States is currently facing a highway funding crisis. Both federal and state transportation budgets are under mounting duress as road maintenance and construction costs continue to outpace revenues each year. While a number of factors contribute to this problem, one of the primary causes is the inherently flawed nature of gas taxes, which provide the vast majority of revenues for the nation's surface transportation system.

In response to growing budgetary shortfalls and the increasingly apparent shortcomings of gas taxes, state and federal policymakers have begun searching for an alternative approach to funding and financing roads. Recently, a concept known as a vehicle miles traveled (VMT) fee has gained popularity among transportation policy experts and policymakers as a potential replacement for the gas tax. Under a VMT fee system, drivers pay for their actual road use instead of, as now, for the motor fuel they consume. Although the concept is new and there exists very little real-world experience with a VMT fee, several pilot studies conducted within the last decade in the United States have demonstrated their potential as a viable, long-term solution to the nation's road funding challenges.

In this paper, I examine the concept of VMT fees and evaluate specific VMT fee systems that have been proposed as alternatives to the gas tax. I begin with an overview of the current gas tax system in the United States and then discuss its advantages and disadvantages as well as why it is not a sustainable funding mechanism going forward. In the second section, I examine the general concept of a VMT fee, including its potential benefits, costs, and the challenges associated with transitioning from the gas tax to a VMT fee. Section three outlines seven essential criteria that specific VMT proposals should meet in order to be considered a viable alternative. In the fourth section, I evaluate four different VMT fee proposals that have been

tested in pilot studies in the United States based on the six criteria spelled out in Section 3. In section 5, I compare and contrast the four proposals and discuss their relative advantages and disadvantages. Section 6 concludes with recommendations for implementing a VMT fee in the United States.

1. THE GAS TAX

For almost a century, motor fuel taxes have served as the primary revenue source for financing the construction and maintenance of America's vast network of roads and highways. Oregon enacted the nation's first gas tax in 1919; by 1932, all states and Washington, D.C. had a gas tax. The federal government also enacted a gas tax in 1932 to reduce the federal deficit. Federal gas tax revenues were not dedicated to funding roads until construction on the Interstate Highway System began in 1956.[1]

Currently, federal gasoline and diesel tax rates are 18.4 cents per gallon and 24.4 cents per gallon, respectively. These taxes comprise approximately 90 percent of monies deposited into the federal Highway Trust Fund, which funds almost all federal surface transportation programs, including 24 percent of all state transportation projects.[2] State gas tax rates vary widely. As of July 2015, the American Petroleum Institute reported that the national averages for state gas and diesel taxes were 30.48 cents per gallon and 30.11 cents per gallon, respectively.[3]

[1] James L. Bickley, "The Federal Excise Tax on Gasoline and the Highway Trust Fund," Congressional Research Service (September 12, 2015), http://fas.org/sgp/crs/misc/RL30304.pdf.
[2] Pew Charitable Trusts, "Intergovernmental Challenges in Surface Transportation Funding" (September 12, 2015), http://www.pewtrusts.org/~/media/Assets/2014/09/SurfaceTransportationIntergovernmentalChallengesFunding.pdf?la=en.
[3] American Petroleum Institute, "State Motor Fuel Taxes" (September 12, 2015), http://www.api.org/~/media/files/statistics/statemotorfuel-onepagers-july-2015.pdf.

Throughout much of their history, gas taxes served the United States well. Their longevity can be attributed to three major advantages. First, gas taxes are easy and inexpensive to administer and collect. The federal government and most states levy their gas taxes on distributors at the time the fuel is removed from bulk terminals. Distributors then pass the tax cost on to retailers, who ultimately pass it on to motorists at the gas pump in the form of higher prices. So, although millions of Americans effectively pay the gas tax, the federal government collects the tax from only about 1,400 distributors while state governments collect from just a couple hundred. As a result, administering the gas tax is estimated to cost only 1 percent of gross revenues.[4]

The second major advantage of gas taxes is that they are difficult to evade and thus enforcement costs are low. With such a small number of collection points, it is relatively easy for the federal and state governments to monitor distributors and uncover through audits attempts to evade the tax. At the consumer level, it is nearly impossible to avoid paying the gas tax because it is included in the price of refueling. This leads to the third, and possibly most advantageous, aspect of the gas tax. Aside from reducing their disposable incomes, because the demand for gasoline is relatively inelastic, gas taxes impose a small excess burden on society as a whole. Refueling is a routine activity for every driver and, hence, total sales decline only modestly in response to the imposition of or an increase in a selective excise tax on gasoline. In fact, most motorists probably do not even notice when they pay the tax.

[4] National Surface Transportation Infrastructure Financing Commission, "Paying Our Way: A New Framework for Transportation Finance," Final Report of the National Surface Transportation Infrastructure Financing Commission, February 2009, http://financecommission.dot.gov/Documents/NSTIF_Commission_Final_Report_Advance%20Copy_Feb09.pdf.

Additionally, as concerns about the environment and especially climate change have risen over the past couple of decades, the gas tax has also come to be viewed as an effective tool to incentivize fuel efficiency and reduce carbon emissions and air pollution.[5]

Most importantly, throughout much of its history, the gas tax provided a steady revenue stream to federal and state governments sufficient to cover road maintenance and construction costs. For more than a decade, however, transportation expenditures have outpaced gas tax revenues, creating serious budgetary problems at all levels of government. Since 2008, the United States Congress has transferred over $65 billion from the general fund to ensure the solvency of the Highway Trust Fund. Absent substantive policy changes, the situation will only get worse. The Congressional Budget Office projects that if current revenue and spending levels remain constant, the nation's Highway Trust Fund will experience a $168 billion shortfall by 2025.[6]

Driving this trend is a combination of skyrocketing transportation spending combined with stagnant gas tax revenues. The spending problem stems from the considerable expansion of the federal surface transportation program since its inception in 1956. Approximately 25 percent of the Highway Trust Fund is diverted every year to public transit, sidewalks, bike trails and other non-highway-related projects.[7]

Yet even if the federal spending problem were resolved, the federal government and the states would still face significant challenges funding highways and roads. This is because the gas

[5] Eduardo Porter, "Taxes Show One Way to Save Fuel," New York Times, September, 11, 2012, http://www.nytimes.com/2012/09/12/business/fuel-efficiency-standards-have-costs-of-their-own.html?_r=0.
[6] James L. Bickley, "The Federal Excise Tax on Gasoline and the Highway Trust Fund," Congressional Research Service, http://fas.org/sgp/crs/misc/RL30304.pdf.
[7] Michael Sargent, "Highway Trust Fund Basics: A Primer on Federal Surface Transportation Spending," Heritage Foundation, http://www.heritage.org/research/reports/2015/05/highway-trust-fund-basics-a-primer-on-federal-surface-transportation-spending.

tax suffers from a number of flaws. These flaws are especially problematic when the gas tax is the primary means of funding and financing roads, as they are in the United States.

At a fundamental level, the gas tax is problematic simply because it is a tax, and raising taxes is challenging politically. Despite growing deficits in the federal highway program, the federal gas tax has not been increased since 1993. States have been more open to gas tax increases over the past few years, however: eight states raised their gas tax between 2013 and 2014 and another 12 states have approved or are considering increases in 2015.[8]

A second and closely related problem is that the federal and most state gas taxes are not indexed to inflation. Between 1956 and 2006, road construction costs increased tenfold. Yet over the same period, federal and average state gas tax revenues grew by barely five times. In other words, current gas tax revenues are only purchasing about half the road construction and maintenance as they did in 1956.[9] Furthermore, if federal gas and diesel tax rates were indexed to inflation when they were last raised in 1993, the current rates would be around 30 cents per gallon and 40 cents per gallon, respectively.[10] Currently, only two states – Maryland and New Hampshire – index their gas taxes to inflation.[11] Massachusetts passed legislation in 2013 that indexed its gas tax to inflation, but the law was repealed by voters in 2014.[12]

A third problem is that even if the federal and all state gas taxes were increased and indexed to inflation, the gas tax would still pose long-term problems for highway funding

[8] Carl Davis, "12 States Could Raise Gas Taxes This Year," Institute on Taxation and Economic Policy, http://www.taxjusticeblog.org/archive/2015/01/12_states_could_raise_gas_taxe.php#.Vgas9_SC6-d.
[9] Randall O'Toole, "Ending Congestion by Refinancing Highways," Cato Institute, http://www.cato.org/publications/policy-analysis/ending-congestion-refinancing-highways.
[10] Ibid.
[11] Joseph Henchman, "State Inflation-Indexing of Gasoline Taxes," Tax Foundation, http://taxfoundation.org/blog/state-inflation-indexing-gasoline-taxes.
[12] Michelle Williams, "Automatic Gas Tax Indexing Repealed by Massachusetts Voters by Close Margin," MassLive.com, http://www.masslive.com/politics/index.ssf/2014/11/massachusetts_question_one_gas_tax.html.

because gasoline consumption is falling. The U.S. Energy Information Administration projects that by 2040, Americans will use around 20 percent less motor fuels relative to current consumption.[13] This is mostly because vehicle fuel efficiency has been rising. When Congress enacted the federal gas tax in 1956, the average fuel economy for vehicles in the United States was 14.4 miles per gallon.[14] In 2014, average fuel economy in the United States had more than doubled, reaching 31.5 miles per gallon.[15] Technological innovation coupled with new federal Corporate Average Fuel Economy (CAFE) standards announced by President Barack Obama in 2012 ensure that the trend toward greater fuel efficiency will continue. Under the new standard, average fuel economy is expected to be 54.5 miles per gallon by 2025.[16] Regardless of whether that ambitious objective is met, fuel efficiency will undoubtedly continue to improve, which will further destabilize gas tax revenues and exacerbate the road funding challenges already facing federal and state transportation officials.

A fourth problem with gas taxes is that they are not a true road user fee. Although motorists need gas in order to drive on roads and the gas taxes they pay are used to fund roads, gas taxes do not account for the fact that some roads cost more to drive on than others. Furthermore, the emergence of electric and alternative-fuel vehicles means that some drivers are paying very little, if anything, for their road use. Not only do these issues call into question the fairness of the gas tax, they also lead to inefficient pricing and overuse of roads, which

[13] U.S. Energy Information Administration, "Fuel Economy Standards Drive Down Projected Gasoline Use; Diesel Use, Product Exports Rise," http://www.eia.gov/todayinenergy/detail.cfm?id=16871.
[14] O'Toole, "Ending Congestion," http://www.cato.org/publications/policy-analysis/ending-congestion-refinancing-highways.
[15] National Highway Traffic Safety Administration, "Summary of Fuel Economy Performance, December 15, 2014," pdf available at http://www.nhtsa.gov/fuel-economy.
[16] National Highway Traffic Safety Administration, "Obama Administration Finalizes Historic 54.5 mpg Fuel Efficiency Standards,"
http://www.nhtsa.gov/About+NHTSA/Press+Releases/2012/Obama+Administration+Finalizes+Historic+54.5+mpg+Fuel+Efficiency+Standards.

contributes directly to America's growing traffic congestion crisis. In its 2015 Urban Mobility Scorecard, the Texas Transportation Institute reported that traffic congestion increased from 2013 to 2014 in 95 of America's 100 largest metro areas. The report estimates that urban traffic congestion caused Americans to travel an extra 6.9 billion hours and cost them $160 billion in 2014.[17]

2. VEHICLE MILES TRAVELED FEES – OVERVIEW, POTENTIAL BENEFITS, AND CHALLENGES

All of the aforementioned problems with the gas tax have prompted policymakers and transportation experts to examine more stable and efficient alternatives to road funding. Recently, proposals for mileage-based user fees (MBUFs), or vehicle-miles traveled (VMT) fees, have started to garner significant attention from federal and state officials, transportation experts, and economists. The concept has also drawn support from across the political and ideological spectrum, as both progressive liberals and free-market libertarians have advocated for some form of VMT fee.[18]

As implied by the name, mileage-based user fees are charges based on distance travelled rather than gallons of fuel consumed. This is a relatively new concept that has become viable because of advances in technology that allow for accurate and reliable monitoring of vehicle miles travelled. As such, there currently is very little real-world experience with VMT fees and

[17] David Schrank, Bill Eisele, Tim Lomax, Jim Bak, "2015 Urban Mobility Scorecard," Texas Transportation Institute, http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/mobility-scorecard-2015.pdf.
[18] See O'Toole, "Ending Congestion" (footnote 14) for a libertarian perspective. For a progressive-liberal perspective, see Kevin DeGood and Michael Madowitz, "Switching from a Gas Tax to a Mileage-Based User Fee: How Embracing New Technology Will Reduce Roadway Congestion, Provide Long-Term Funding, and Advance Transportation Equity," Center for American Progress, https://www.americanprogress.org/issues/tax-reform/report/2014/07/11/93657/switching-from-a-gas-tax-to-a-mileage-based-user-fee/.

although the general idea of such a system is drawing wide support, no consensus regarding how one should be implemented or operated has emerged.

As evidence of the VMT fee's growing popularity, at least 13 states have considered legislative proposals to study or establish such a system.[19] The concept has also been recommended by two different federal transportation commissions that were created to research viable long-term solutions to the highway funding crisis,[20] as well as the Congressional Budget Office.[21] Additionally, Congressman Earl Blumenauer of Oregon has sponsored legislation that would establish a national VMT pilot study to determine if such a system could serve as a viable alternative to the federal gas tax.[22]

A VMT system promises a number of potential advantages over the gas tax. First, it could provide a more reliable, long-term road funding mechanism because revenues would not depend on gasoline consumption or improving vehicle fuel efficiency standards. In addition, all drivers would pay into the system under a VMT structure, including drivers of electric and alternative fuel vehicles, which also makes a VMT fee fairer in this regard.

A second advantage is that a VMT fee would more closely resemble a true road user fee. Under the existing gas tax system, drivers are charged for the fuel they consume, not the specific

[19] Paul Epstein, "States Taking a Larger Role in Transportation Funding," Law360.com, http://www.law360.com/articles/630949/states-taking-a-larger-role-in-transportation-funding
[20] National Surface Transportation Policy and Revenue Study Commission, "Final Report," December 31, 2007, http://transportationfortomorrow.com/final_report/vol_1_chapter_1.htm; and National Surface Transportation Infrastructure Financing Commission, "Paying Our Way: A New Framework for Transportation Finance," February 26, 2009, http://financecommission.dot.gov/Documents/NSTIF_Commission_Final_Report_Advance%20Copy_Feb09.pdf.
[21] Congressional Budget Office, "Alternative Approaches to Funding Highways," March 23, 2011, https://www.cbo.gov/publication/22059?index=12101&zzz=41624.
[22] Press release on Congressman Blumenauer's official website, "Blumenauer Introduces Innovative VMT Proposal to Address Highway Trust Fund Deficit," http://www.blumenauer.house.gov/index.php?option=com_content&view=article&id=1528.

roads they use. Under a VMT fee, drivers would pay for the distance traveled regardless of their vehicle's fuel efficiency or the type of fuel used.

A third advantage offered by a VMT fee is the potential for more efficient and transparent pricing. Drivers would be able to calculate the exact cost of different routes and adjust their travel accordingly. Not only would this provide drivers with clear signals and encourage them to make more efficient travel decisions, it would also provide transportation authorities with accurate information about which roads were in high demand and where to invest in maintenance and new infrastructure.[23]

A fourth major advantage is flexibility. Under a VMT system, governments could pursue a number of different policy goals aside from stable road funding. For example, a VMT fee could be designed to alleviate traffic congestion. America's congestion problems have already been noted and the potential for differential pricing offered by a VMT system could be an effective solution. Fees could be structured in such a way that drivers would be charged significantly more per mile during peak travel times on heavily congested roads. This would reduce congestion by encouraging people to use alternate routes, carpool, find other modes of transportation, or alter the times during which they travel.

VMT fees also present a number of challenges and potential disadvantages, however, which must be addressed sufficiently in order for such a system to be successful. Without question, the biggest obstacle to implementing a VMT fee will be gaining widespread public

[23] O'Toole, "Ending Congestion."

acceptance. Transportation experts and public officials may be on board, but surveys show that the general public is still very wary of VMT fee proposals.[24]

This shouldn't be surprising since a VMT fee is such a new concept that the general public does not yet understand how it works. Regardless of how a VMT system is designed, it will require extensive public outreach and education efforts to earn public support. For example, to build support for VMT pilot studies and eventual statewide implementation in Oregon, state transportation officials executed an aggressive media campaign, including local newspaper op-eds and radio advertisements, held numerous community and stakeholder meetings, and set up a website and a blog with detailed information regarding the system's design and the implementation process.[25]

Aside from fear of the unknown, the concern most commonly cited by the public with regard to a VMT fee is privacy. Most legitimate VMT proposals require a device, such as a global positioning system (GPS), to be installed in vehicles to monitor distances traveled and calculate mileage fees. With Americans already leery of the government tracking their communications, it is entirely understandable that they would not want to allow the government to track them while they drive. Fortunately, as demonstrated later in this paper, existing technologies can be designed such that no location data are transmitted to government agencies as part of VMT fee collection. But extensive public outreach will be essential to demonstrate the efficacy of these privacy controls if a VMT fee is to gain adequate support.

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[24] Trey Baker, Ginger Goodin, and Chris Porteau, "Is Texas Ready for Mileage Fees?" Texas Transportation Institute, http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/0-6660-P1.pdf; and Nevada Department of Transportation, "Nevada Vehicle Miles Traveled Fee Study, Phase I," http://www.nevadadot.com/uploadedFiles/NDOT/Documents/VMT%20FEE%20STUDY%20Bk.pdf.

[25] James M. Whitty, "Oregon's Mileage Fee Concept and Road User Fee Pilot Program: Final Report," *Oregon Department of Transportation*, November 2007, http://www.oregon.gov/ODOT/HWY/RUFPP/docs/RUFPP_finalreport.pdf.

In addition to general concerns, VMT supporters will also have to target specific subsets of the population who are wary that a VMT fee will disproportionately impact them in one way or another. One such group is rural motorists who, it has been argued, often have to drive more miles than their urban counterparts and would therefore pay disproportionately more under a VMT system.[26] Researchers at Oregon State University, however, have shown that this concern likely is overstated. They determined that although rural drivers may drive longer distances in some instances, overall, there is a less than a 10 percent difference between rural and urban driving.[27]

Similarly, a Nevada Department of Transportation study concluded that "[i]t is a general and common misconception that rural residents and people who have longer commute[s] will pay more under a VMT Fee system… [T]he more we drive the more we pay in fuel cost and fuel taxes under the current fuel tax system. This will not be any different under the VMT Fee system; the more we drive, the more we will pay in VMT fees."[28] The study also points out that rural drivers may actually pay less under a VMT fee system because rural drivers tend to drive less fuel-efficient vehicles and thus pay more in gas taxes.[29]

Another key group that has expressed skepticism about a VMT system is the trucking industry. One of the group's major concerns is how trucks would fare under a patchwork of different state-based VMT fees if states, rather than the federal government, take the lead in implementing VMT fees. To date, none of the VMT pilot studies conducted in the United States

[26] Cynthia Lummis, "Vehicle Miles Traveled Tax Would Be Unfair to Rural Americans," July 21, 2011, http://www.rollcall.com/features/Transportation-2011_Policy-Briefing/policy_briefings/Cynthia-Lummis-VMT-Tax-Would-Be-Unfair-to-Rural-Americans-207560-1.html.
[27] B. Star McMullen and Lei Zheng, "Social-Economic Impact of a Vehicle Mileage Tax," Oregon State University and Oregon Department of Transportation Research, August 1, 2007.
[28] Nevada Department of Transportation, "Nevada Vehicle Miles Traveled Fee Study, Phase I," December 2010, p. 2, http://www.nevadadot.com/uploadedFiles/NDOT/Documents/VMT%20FEE%20STUDY%20Bk.pdf.
[29] Nevada DOT, "Nevada Vehicle Miles Traveled Fee."

have included trucks and the issue has not yet received significant attention. In the future, if states choose to add commercial trucks to their VMT fee systems, interoperability concerns will have to be addressed.

Other countries, such as Germany, Switzerland, and Austria, have had success implementing distance-based fees on commercial trucks. Germany uses GPS-based devices to track and charge commercial trucks per kilometer traveled on the country's autobahn system. The charges vary based on the number of axles and emission class. Since the fee was implemented in 2005, findings indicate greater efficiency in Germany's heavy vehicle industry and overall benefits to the German economy. However, there are significant differences between the freight and logistics systems in the United States and Germany, so it cannot be assumed that such a system would be successful in the United States.[30]

A third group that is opposed to VMT fees comprises those who support the gas tax as a means of encouraging people to drive fuel-efficient and alternative-fuel vehicles. Replacing the gas tax with a VMT fee, they argue, will eliminate this incentive, which has implications for the environment, air quality, and climate change.[31] This objection was raised frequently by environmentally conscious Oregonians over the course of Oregon's two VMT pilot studies. James Whitty, the author of both studies' final reports, offered two counterarguments. First, gas taxes represent a relatively small portion of the total cost of fuel. Researchers at Oregon State have found evidence indicating that people purchase fuel-efficient vehicles because of the cost of gas, not taxes or fees. Thus, eliminating gas taxes likely would have little to no effect on peoples'

[30] National Surface Transportation Infrastructure Financing Commission, "Paying Our Way," http://financecommission.dot.gov/Documents/NSTIF_Commission_Final_Report_Advance%20Copy_Feb09.pdf.
[31] Ben Adler, "Why It's A Bad Idea to Tax People for Every Mile They Drive," May 12, 2015, http://grist.org/climate-energy/why-its-a-bad-idea-to-tax-people-for-every-mile-they-drive/.

decisions to drive fuel-efficient cars. Second, a mileage fee is not meant to address all possible policy goals. Environmental concerns can be more effectively spoken to by other policies.[32]

Beyond privacy, equity, and environmental concerns, another challenge with a VMT fee will be determining the appropriate fee rates and structures such that sufficient revenues are raised but fees aren't so high that drivers reject the concept. As the authors of the Minnesota Road Fee pilot study report (discussed below) put it, "the rate setting process is very complex and an area that is still not well understood in this context."[33]

A related problem is that a VMT fee likely will be just as difficult to increase as the gas tax if revenues are not sufficient. It is imperative that policymakers set initial VMT rates at levels that will provide sufficient revenues for road funding. Also, unless policymakers index the fee to inflation or establish another means of raising the fee automatically, a VMT system will likely face the same long-term problems as the gas tax.

3. EVALUATING VMT FEE SYSTEM PROPOSALS

The preceding discussion highlighted general concerns and challenges that policymakers should consider throughout the initial stages of researching and conducting pilot studies for VMT fees. In this section, I turn to the design and operation stages of VMT fees and describe how VMT fees should work in practice. Specifically, I outline six essential criteria that all VMT systems should meet. These criteria are then used to evaluate four different VMT fee proposals in the next section.

[32] Whitty, "Oregon's Mileage Fee Concept," http://www.oregon.gov/ODOT/HWY/RUFPP/docs/RUFPP_finalreport.pdf.
[33] Jennifer A. Rephlo, "Connected Vehicles for Safety, Mobility, and User Fees: Evaluation of the Minnesota Road Fee Test," Minnesota Department of Transportation, February 2013, http://www.dot.state.mn.us/mileagebaseduserfee/pdf/EvaluationFinalReport.pdf, p. 159.

To be clear, the following list of criteria is not exhaustive. There are countless criteria and metrics by which VMT fee systems can be judged. The criteria used here were chosen based on my review of the VMT fee research literature. I selected the criteria that were cited most commonly and those that I deemed necessary to make a VMT fee a viable alternative to the gas tax.

Criterion #1: Privacy Protection

As already noted, privacy is one of the greatest concerns surrounding GPS-enabled VMT fees. Many Americans are uncomfortable with the prospect of government officials having the ability to track and keep records of where they drive. Therefore, any VMT fee system must be designed to limit government access to motorists' personal data and locations. Specifically, the National Surface Transportation Infrastructure Financing Commission (NSTIFC) has identified three key privacy-related considerations for a full-scale VMT fee implementation: "how information about where and when a vehicle traveled would be identified and recorded, who would physically own and control this information, and how and in what form the information would be communicated to the administering agency for billing and collection purposes."[34]

In short, a VMT fee system that protects drivers' privacy will restrict the government's access to vehicle tracking information, allow drivers or the private sector to control this information to the greatest possible degree, and ensure that all information and data are transmitted securely. The privacy protection scores for each of the proposals examined later in this paper are based on these considerations.

[34] National Surface Transportation Infrastructure Financing Commission, "Paying Our Way," p. 151.

It is important, however, to recognize the tradeoff that exists between privacy and auditability, which is discussed in more detail below. Namely, the less data made available to government administrators, the more difficult it will be to verify the accuracy of mileage charges. For example, motorists who believe they have been overcharged will find it difficult to challenge if the data are not stored or accessible to them or the government.

Criterion #2: Technological Reliability

VMT fees will require governments and drivers to utilize far more technology than they currently do with gas taxes. Thus, in order for a VMT system to function as a viable replacement for gas taxes, it is imperative that all of the technology used in a VMT system works reliably. The technologies used in the VMT fee proposals examined in this paper vary considerably so each proposal is evaluated based on the reliability and functionality of the technologies specific to that proposal. However, because each proposal relies on some form of GPS technology, there are some common criteria that can be applied across all of the proposals. Namely, GPS devices must, at a minimum:

- accurately track vehicles' locations with minimal signal loss and distinguish between jurisdictions;
- accurately measure distance travelled;
- correctly calculate the associated fees; and
- reliably transmit the correct information to the proper location.

Most devices used in VMT proposals, including all four of the proposals in this paper, are designed to include additional features and applications beyond just location tracking and mileage counting, such as congestion pricing and safety alerts. Although these features may offer

many benefits, it is important to recognize that the more complex the system, the greater the opportunity for technological failure.

Criterion #3: User-friendliness

Most VMT fee proposals necessarily require more actions on the part of drivers than required under the gas tax. Drivers may be required to interact with new technologies and may have to pay a monthly bill, for example. However, in order to gain widespread public acceptance, such new actions should be minimal. The administering government must consider user-friendliness at all levels of a VMT system, including:

- Installing the on-board unit – ideally, motorists will be able to quickly and easily install the technology themselves. If this is not feasible, the next best alternative is a technology that can be installed quickly, easily, and inexpensively, preferably by the private sector.
- Operating the on-board unit – operating interactive devices may prove challenging for some drivers and should therefore be made as simple as possible without affecting functionality. The more complex the system and the more features that are incorporated, the more difficult this becomes.
- Billing and payment processes – receiving invoices and paying mileage fees should be simple and fast. Drivers should be made fully aware of the frequency of billing cycles and be given options for paying their bills, such as electronically or in person.

The unique aspects of each VMT proposals will dictate how governments approach user-friendliness, but the overarching goal should be to add as little burden and require as few new actions as possible from motorists relative to their experience with the gas tax.

Criterion #4: Minimal Evasion and Fraud Potential

VMT fees present more opportunities for evasion and fraud than gas taxes. One of the most evident challenges of a VMT fee system is the potential for tampering with the odometer or on-vehicle device that measures mileage, calculates fees, and transmits data to the collecting entity. To date, very little research has been done regarding evasion and fraud prevention in a full-scale VMT fee system. The Transportation Research Board has noted that "several distinct, and potentially complimentary, approaches have been proposed," but "the best option is not yet clear."[35] Two of the most commonly cited safeguards associated with a VMT fee system are redundancy checks and tamper-resistant technologies.

Redundancy checks involve regular comparisons between the on-board device and the vehicle's odometer to ensure that neither has been altered manually. However, periodic vehicle inspections may be required for such comparisons, which would increase burdens and costs to drivers. Another strategy is to design devices so that motorists cannot easily disable them, and, if the devices are disabled, it should be easily detectable by the government or private sector.[36]

Criterion #5: Cost-Effectiveness

Despite all of the potential advantages a VMT fee has over the gas tax, those advantages will likely impose additional burdens to taxpayers as a VMT fee will undoubtedly cost more to implement and administer than the gas tax. The goal of a VMT system, therefore, is to minimize those added costs to the greatest extent practicable. Specifically, there are four categories of costs associated with a VMT fee: (1) startup costs, which include capital and infrastructure costs necessary to establish the system and any retrofitting of vehicles or other technologies that may

[35] Paul Sorenson, et al., "Implementable Strategies for Shifting to Direct Usage-Based Charges for Transportation Funding," Transportation Research Board, June 2009, http://www.rand.org/content/dam/rand/pubs/reprints/2009/RAND_RP1395.pdf, pp. 56-57.
[36] Ibid., p. 57.

be required; (2) operation and maintenance costs; (3) enforcement and auditing costs; and (4) billing and collection costs.

Because no large-scale VMT system exists in the United States and the only available data are from small-scale pilot studies, the actual costs of implementing and administering a VMT system on a statewide, region-wide, or nationwide scale are largely unknown. The Federal Highway Administration has estimated that the costs of implementing a nationwide VMT fee likely would include at least $10 billion in initial capital costs plus operating costs of around 1.7 percent of gross revenues.[37] Actual costs, however, will depend on how the system is designed and administered.

For my evaluation of the cost-effectiveness of each proposal discussed in this paper, I rely on the best cost estimates and analysis provided in the final reports of the pilot studies.

Criterion #6: System Flexibility

Because the concept of a VMT fee is relatively new, and any VMT fee system likely will need to be phased in gradually and involve at least some trial-and-error, it is important that VMT fee proposals are designed in such a way that they can be altered easily as policymakers and the public learn what works and what doesn't work. For example, it may take time and experience to learn the optimal per-mile fees. The system should be designed to allow policymakers to make rate changes quickly, such as through a simple electronic upload to the system's software.

Furthermore, initial implementation of a VMT fee likely will have to start out very simple and address only one or two major policy goals as policymakers and motorists get

[37] Joint Committee on Taxation Staff Report, "Long-Term Financing of the Highway Trust Fund," June 15, 2015, accessed at https://www.jct.gov/publications.html?func=startdown&id=4790.

comfortable with the new system. However, the system should be designed to allow policymakers to address new policy objectives, such as congestion pricing, for example, and change existing ones as people get accustomed to the system and new ideas and technologies emerge.

4. VMT FEE SYSTEM PROPOSALS

In this section, I discuss four VMT fee proposals and evaluate them based on the above criteria. I chose these four proposals because all have been tested in pilot studies in the United States and final reports have been published for each study, which provided me with the information necessary to conduct my own evaluations. For each proposal, I provide background information detailing the design of the proposed system and the structure of the pilot study in which it was tested. I then evaluate the system by discussing how the proposal rates on the six criteria outlined above.

To help the reader compare and contrast the different proposals, I provide a numeric rating for each of the criteria under each proposal. I use a numeric rating scale from 1 to 4, with 4 being the highest score and indicating that a proposal fully satisfies a particular criterion, and 1 being the lowest, signifying that the proposal does not meet any portion of the criterion. More specifically, a score of 4 means that the proposal meets that particular criterion to such a degree that under a real-world implementation, there would be little if any concern among the general public or the administering government. For example, a privacy protection score of 4 signifies that the proposal provided exceptional privacy protection and likely eliminate most concerns among motorists that their privacy would be violated.

A score of 3 means that the proposal adequately meets a particular criterion and would likely be acceptable to the public and the administering government in a real-world implementation, but improvements could be made. A privacy protection score of 3 would indicate that although the system provided sufficient protections necessary for successful implementation and operation, legitimate concerns may remain that should be corrected or mitigated in the future.

A score of 2 means that the proposal only partially meets a criterion and is likely insufficient for real-world implementation unless substantial improvements are made. If the privacy protection criterion receives a 2, it suggests that there are likely to be significant public concerns about the security of private information and will trigger objections to the system being implemented. Policymakers would need to improve privacy protections or develop a different policy altogether before the system could be implemented successfully.

A score of 1 signifies that the proposal fails to meet a criterion and indicates the need for a wholly different policy or strategy to satisfy the criterion. A privacy protection score of 1, for example, means that the proposal does not offer any fundamental privacy safeguards and would be rejected by most drivers.

In some instances, there was not enough information to assign a rating for certain criteria. These are designated as N/A.

Proposal #1: University of Iowa's Mileage-Based Road User Charge[38]

[38] All information and data in this section were obtained from Paul F. Hanley and John G. Kuhl, "National Evaluation of Mileage-Based Charges for Drivers: Initial Results," Transportation Research Record: *Journal of the Transportation Research Board* No. 2221, Washington, D.C., 2011, pp. 10-18. DOI: 10.3141/2221-02.

Of all the proposals discussed in this paper, this one had by far the least amount of published information. The University of Iowa's final report on the pilot study consisted of a brief nine-page report in the *Journal of the Transportation Research Board*. As such, I was limited in my ability to evaluate this particular proposal.

From 2008 to 2010, the University of Iowa Public Policy Center conducted a VMT fee pilot study that included approximately 2,650 volunteers from 12 states. This was the first pilot program conducted on a national and multijurisdictional scale in the United States. Under this system, vehicles were outfitted with an onboard computer (OBC) that was equipped with a GPS receiver that contained a geographic database to identify different taxing jurisdictions. This enabled the system to allocate fee revenues to the appropriate level of government, either federal, state, or local, depending on the location of the vehicle. Also stored in the OBC was a file containing per mile charges for each participating jurisdiction. The OBC was not interactive.

The OBC connected to the vehicle's speedometer and odometer to calculate miles travelled while the GPS tracked the vehicle's location. However, the OBC did not transmit or store any GPS coordinates or other information that could be used to determine the location of individual vehicles beyond the jurisdiction in which they travelled.

The system relied on cellular communications using standard commercial cellular data services to transmit mileage charges to a network operations center. The operations center then sent the data to a central billing center that prepared and sent monthly invoices to participants. The network operations center was also able to transmit updates to the OBCs regarding mileage fee changes or jurisdictional boundary changes.

Criterion #1: Privacy Protection

Drivers' privacy was well protected under this system because no GPS coordinates or other location-specific information were stored on the OBC or transmitted to the operations center. In fact, in post-study questionnaires, participants indicated that the privacy protections were too strong. Nearly 68 percent of participants said they would have preferred less stringent privacy protections to allow for more detailed monthly invoices that included at least some location information for auditability.

Privacy Protection Score: 4

Criterion #2: Technological Reliability

The technology utilized in the system was simple and generally performed well throughout the study. The OBC accurately measured 92.5 percent of all miles travelled while 6.9 percent of miles were assigned reliably to the correct jurisdiction using simple interpolation techniques with known data points. In all, only 0.6 percent of miles travelled could not be accounted for. No problems were encountered with the cellular network, communications, or infrastructure. Over the course of the study, three rate changes were uploaded to the system without any issues.

The technology wasn't perfect, however. The OBC caused electrical failures in a small group of certain vehicle models. In a widespread implementation scenario, this problem would likely be resolved by working with the manufacturer and the developers of the OBC software, but this does highlight the importance of making sure that the technology used in a VMT system is compatible across all vehicle makes and models. Also, even though less than 7 percent of miles travelled were not accurately tracked by the GPS receiver, this would pose a significant

problem if congestion pricing on specific roads or lanes were introduced under this system, as road- or lane-specific pricing would require much greater precision to be assessed accurately.

Technological Reliability Score: 3

Criterion #3: User-Friendliness

The operation and administration of the system were simple and required minimal new actions by the participants. Because the OBC was not interactive, drivers did not have to learn how to operate it. Charge data were transmitted regularly without any participant involvement. The only added burden to the motorist was paying the monthly bill on time, which was done electronically. There were substantial problems with installing the OBC, however, which required a professionally trained technician and took approximately 90 minutes. In a full-scale implementation scenario, this would not be practicable.

User-Friendliness score: 2

Criterion #4: Minimal Evasion and Fraud Potential

Fraud and evasion issues were not addressed in the study. The final report does mention that the OBC held charge data for several months in the event that vehicles travelled outside the cellular network's coverage area and charges could not be uploaded for a long period of time. This would prevent drivers from avoiding paying the charge by travelling outside the coverage for a few days. Because there was very little information presented for this criterion, I do not provide a score.

Minimal Evasion and Fraud Potential score: N/A

Criterion #5: Cost-Effectiveness

The final report provided no information regarding the costs of implementing or administering this system so a rating cannot be assigned on this criterion. One positive sign in this regard, however, is that the system was able to operate on standard commercial cellular data services so presumably little new technology or infrastructure would be required.

Cost-Effectiveness score: N/A

Criterion #6: System Flexibility

This system was designed to allow for future jurisdiction additions and rate changes. Mileage charge rates were easily updated through the cellular network and could be varied based on a number of factors, including vehicle type and class. In the pilot study, vehicles were divided into 20 different categories based on their average fuel economy as determined by standards established by the Environmental Protection Agency. Separate mileage charge rates were assessed based on each vehicle's classification. For example, a vehicle with greater fuel efficiency was charged less per mile than a less efficient vehicle. This is one way for policymakers to encourage vehicle fuel efficiency under a VMT fee system.

There are two drawbacks with respect to the flexibility of this system. First is the aforementioned imprecision of the GPS receiver, which limits the system's ability to incorporate road-specific or single-lane congestion pricing. Second, the system utilizes a single, government-selected device and only the administering government can add to or modify the features of the software. This prevents the private sector from innovating and offering ancillary features to motorists.

System Flexibility score: 2

Summary Analysis:

Although the system provides strong privacy protections and the OBC performed its basic functions reasonably well in the pilot study, it is hindered by the indefensibly expensive OBC installation process and lack of flexibility. The government-designed and mandated device eliminates consumer choice and precludes private sector innovation. Under a real-world implementation, the government should allow the private sector to develop different OBCs to offer drivers more choice and to allow for the addition of new features in the future.

The lack of any discussion of costs in the pilot study's final report ultimately makes any analysis of this proposal difficult. By utilizing existing technologies and infrastructure, the system likely would avoid significant upfront capital costs, but if a new government-designed and mandated device is developed to make the installation process easier, capital costs would increase.

Proposal #2: Minnesota Road User Fee[39]

The Minnesota Road User Fee concept was tested over a twelve-month period from 2011 to 2012 in the Twin Cities Metro Area. This system utilized an existing smartphone equipped with standard GPS and navigation capabilities, and an application that calculated, stored, and transmitted VMT fees. A vehicle identification module (VIDM) was also connected to the vehicle's on-board diagnostic port (OBD-II) behind the steering wheel. When the vehicle was started, the smartphone connected wirelessly to the VIDM to ensure that the phone was in the correct vehicle and that the phone's mileage readings were consistent with the odometer. In order to make sure that drivers were using the phones when they drove and that the phones were

[39] All information and data in this section were obtained from Jennifer A. Rephlo, "Connected Vehicles for Safety, Mobility, and User Fees: Evaluation of the Minnesota Road Fee Test," Minnesota Department of Transportation, February 2013, http://www.dot.state.mn.us/mileagebaseduserfee/pdf/EvaluationFinalReport.pdf.

accurately tracking miles, drivers were required to schedule regular odometer checks at their local Division of Motor Vehicles office.

To promote fairness and to mitigate traffic congestion on high-traffic roadways, fee rates in the pilot were varied based on the location and time of travel. The fee system was structured as follows:

- No charge for miles driven outside the State of Minnesota.
- $0.01 per mile driven outside predefined "Twin Cities Metro Zones" (TCMZs) and inside TCMZs during off-peak hours.
- $0.03 per mile driven inside TCMZs during peak traffic hours.
- $0.03 per mile driven without the smartphone in the vehicle and powered on.

In addition to a VMT fee, the system also included a novel safety signage feature. The phone application was designed to identify "safety zones," such as school and construction zones and upcoming sharp turns in the road. When the vehicle entered these zones, the phone would display the reduced speed limit or warning sign about the upcoming turn, along with an audible tone. If the vehicle exceeded the speed limit within these zones by more than 5 mph, the phone would sound another alert tone.

The system utilized an existing cellphone carrier's 3G data network to transmit data from the phone to a central billing office, which generated monthly invoices and sent them to drivers electronically via the app, email, and, if the driver requested it, via traditional mail. The invoices itemized fees by category, such as out-of-state miles, miles driven within TCMZs, and miles driven during peak hours. Invoices were paid electronically through the app, on the website, or in person at one of the field offices.

Criterion #1: Privacy Protection

During the pilot study, the system collected large amounts of data from each vehicle, including the number and length of trips per day, the number of trips through "safety zones", and second-by-second data for each trip, such as vehicle speed, heading, timestamp, and GPS accuracy. Yet most of the data were collected for research purposes and would not be necessary under full implementation. Further, unless drivers had consented to allow the researchers access to their detailed driving data, the only data traceable to individual drivers were those that appeared on the invoices.

Privacy Protection score: 4

Criterion #2: Technological Reliability

The smartphone technology utilized in this design proved to be inadequate on a number of levels. First, the phones frequently had difficulty establishing a connection with the VIDM when vehicles were started. As a result, the pilot study researchers determined that 52 percent of trips during the study contained "unrealistic or questionable characteristics."[40]

Furthermore, even when the phone did make a proper connection with the VIDM, the phone recorded only 76 percent of miles traveled during the study. Users reported that oftentimes the phone displayed an error message stating that the GPS signal was weak or disconnected. This is significant because in order to encourage drivers to use the phone while they traveled, drivers were automatically charged the highest rate – $0.03 per mile – for all miles that weren't recorded by the phone. Additionally, 10 percent of participants' phones recorded *more* miles than the

[40] Ibid., p. 69.

odometer. Other issues also cropped up, such as phones freezing or suddenly shutting off during trips, and weakened performance and battery life in extreme hot or cold weather.

In the final report the researchers ultimately concluded: "Smartphones are quickly changing and improving, and the quality of GPS chips in smartphones in the near future may very well be better-suited for this kind of application, but it may be too early at this time to rely on smartphone technology to achieve the level of accuracy expected/desired for an MBUF program."[41]

Technological Reliability score: 1

Criterion #3: User-Friendliness

Since the system utilized a standard smartphone and the VIDM connected directly into the vehicle's OBD-II, installation procedures were relatively simple and could be performed quickly by the motorist or, if necessary, with assistance from a technical support team member. In general, the study participants found the phone and the application easy to use, although some had difficulty turning on and off the GPS functionality. In a real-world implementation, there would surely be those who are not accustomed to using smartphones and applications and might therefore struggle with operating the device, at least initially. However, the researchers found that as the study progressed and drivers became more experienced with the smartphone and the application, their comfort levels increased and the number of customer service calls declined over time.

Many drivers did not like having to remember to bring the phone with them every time they drove, and they didn't appreciate having to pay the higher fee rate when they forgot the

[41] Ibid., p. xxxi

phone. The researchers noted, "again and again, participants in the MRFT expressed a desire for the technology to be integrated into the vehicle so that it would require little (if any) interaction on their part."[42]

Finally, requiring periodic odometer checks to ensure compliance and system accuracy would add another burden to drivers. One possible solution is use regular vehicle inspections to check odometers, but drivers and policymakers may want to monitor accuracy and compliance more frequently.

User-Friendliness score: 2

Criterion #4: Minimal Evasion and Fraud Potential

Three primary enforcement mechanisms were put in place in the pilot study to prevent evasion. The first was regular odometer checks to ensure that drivers turned on the smartphones while driving. The second was charging a higher rate for all miles not recorded by the smartphone. The third mechanism related to late payments. If drivers did not pay their previous month's bill within 15 days of the due date, their phone was disabled and they were charged the higher rate for all miles traveled that month. To restore their phone's functionality, drivers had to pay the overdue fee and schedule a meeting with a member of the technical support team at a local field office.

The researchers noted that additional enforcement mechanisms will have to be employed under real-life implementation, such as penalties for and efforts to detect and deter odometer tampering, and including on a person's driving record whether he or she has unpaid mileage fees.

[42] Ibid.

Minimal Evasion and Fraud Potential score: 3

Criterion #5: Cost-Effectiveness

The Minnesota researchers were reluctant to offer a detailed cost analysis because the costs involved in administering the pilot study are not representative of the costs that could be involved in a real-life implementation. The researchers note that many of the costs incurred in the pilot study would likely be much less in a full implementation scenario because mass production and familiarity with a fully implemented system would increase efficiency and decrease costs such as per-unit phone costs.[43]

Also, because this system relies largely on existing technologies like smartphones, cloud-based data storage, and the 3G wireless network, and because it would require very little new infrastructure, the upfront costs might not be as high as other VMT proposals that require the development of new hardware, software, and infrastructure. Additionally, many Americans already own a smartphone and would not need to purchase additional hardware in order to participate in the system. A simple application download is all that is necessary. For those who do not own smartphones, under a full-scale implementation, cell phone companies likely would start offering phones and data plans tailored specifically for a VMT fee, which could drive down costs even further.

As with most VMT fee proposals, this one would entail more administrative and operations costs relative to the gas tax. For example, it would be necessary to create and manage a dedicated website and a central billing office, train and hire a technical support team and more technicians at the DMV for odometer readings, and added enforcement costs. Although the

[43] Ibid., p. 219.

information is incomplete, this system appears to be a relatively cost-effective option for a VMT fee.

Cost-Effectiveness score: 3

Criterion #6: System Flexibility

The greatest advantage of this system is its flexibility. Although only two major pricing variations – time- and location-based – and only one additional feature – safety signage – were implemented in the pilot study, there is potential for addressing a number of policy objectives under this system. For example, the researchers noted that once drivers are comfortable with a basic VMT system, policymakers could introduce more complex pricing systems such as variable pricing based on roadway type and jurisdiction.[44]

Policymakers could also expand upon the safety signage feature or add other features by simply modifying the smart-phone application. Further, if the system is designed as an open source system, private sector software developers could create applications compatible with the VMT system to give drivers and policymakers even more options, such as pay-as-you-go auto insurance.[45]

Flexibility score: 4

Summary Analysis:

The Minnesota Road User Fee is a promising concept but is unfortunately not ready for real-world implementation at this time. The system provides strong privacy protections and offers a cost-effective and highly flexible system that can seamlessly integrate new features and

[44] Ibid., p. 12.
[45] Ibid., p. 238.

policy objectives over time. Unreliable cellphone GPS technology effectively renders the system unworkable, however, until the technology improves significantly. Also, if the pilot study is any indication, many drivers may prefer a device integrated in the vehicle over a smartphone that they must remember to bring with them on all trips.

Proposal #3: Oregon Mileage Fee Concept[46]

The Oregon Mileage Fee Concept (OMFC), which was demonstrated in a 12-month pilot study from 2006 to 2007, marked the first of two VMT pilot studies carried out by the Oregon Department of Transportation (ODOT). The OMFC study involved 299 participants and two gas stations in Portland, Oregon. Realizing that public acceptance would be critical to the success of a future statewide VMT fee implementation, ODOT's primary goal was to create a simple VMT system that motorists, at least initially, would barely recognize as being different from the state's existing gas tax system. Thus, the OMFC relied on a pay-at-the-pump concept that required virtually no new actions from motorists.

Each vehicle was equipped with a custom on-board unit (OBU) designed specifically for the pilot study. The OBU consisted of a small display screen, a GPS receiver, a mileage counter, and a short-range radio frequency antenna. The OBU connected directly to the vehicle's power outlet and was usually mounted to the windshield using a suction mount. Although the system allowed for mileage fees to be varied based on the location and time of driving, such as for congestion pricing, in the field study motorists paid a flat fee for all miles driven in Oregon. Motorists were not charged for miles driven outside of the state. For miles not captured by the

[46] All information and data in this section were obtained from James M. Whitty, "Oregon's Mileage Fee Concept and Road User Fee Pilot Program: Final Report," *Oregon Department of Transportation,* November 2007, http://www.oregon.gov/ODOT/HWY/RUFPP/docs/RUFPP_finalreport.pdf.

GPS device, motorists paid the gas tax. The OBU screen displayed the zone in which the motorist was travelling and the associated mileage fee.

Similar to the gas tax, drivers paid the mileage fees when they refueled their vehicles. The short-range radio antenna transmitted the mileage data, which was stored in the OBU, to the gas pump, which was retrofitted with a "reader" that identified the vehicle, calculated the mileage fee, and deducted the gas tax. Receipts from fuel purchases displayed the amount of fuel purchased, the amount of gas taxes deducted, the number of miles driven in each zone since the last refueling, and the associated mileage fees.

Criterion #1: Privacy Protection

A number of factors ensure motorist privacy in the OMFC. First, all data are stored in the OBC, not in a centralized data collection system, so the government would have almost no access to personal data. Second, the government would have no involvement in developing, installing, or maintaining the OBDs. Per ODOT's final report:

> In the Oregon system, private companies create the on-vehicle devices, automobile manufacturers or dealers install the devices, service stations extract the necessary data for mileage charging and the private sector maintains and repairs the devices. The Oregon system does not give the state government access to the on-vehicle devices except, perhaps, to investigate device tampering. [47]

[47] Ibid., p. 60.

Third, no real-time or past travel location data are transmitted to the government. Data transmission capabilities are limited to short-range transfers of mileage data between the vehicle and the fuel pump.

One potential privacy issue arises with vehicles being identified at the pump. Although not nearly as invasive as second-by-second location tracking, this would nonetheless enable the government to track where vehicles had been refueled, which might make some motorists wary.

Privacy Protection score: 3

Criterion #2: Technological Reliability

The OBU functioned well throughout the study. The GPS receiver accurately recorded mileage and distinguished between miles driven inside and outside of the state. Problems arose, however, with the radio transmitters and receivers on the cars and fuel pumps. At one of the gas stations utilized in the study, vehicles successfully communicated with the pumps 88 percent of the time and at the other gas station, successful vehicle-to-pump communication occurred only 73 percent of the time. As a result, drivers paid the gas tax instead of the VMT fee. The researchers concluded that "the vehicle-to-pump association was not sufficiently reliable," and that "further research is required prior to statewide implementation."[48]

Technological Reliability score: 2

Criterion #3: User-Friendliness

As already mentioned, the chief objective of the OMFC was to ensure public acceptance by designing an easy-to-use system. OMFC largely achieved that goal. By retaining the pay-at-

[48] Ibid., p. 35.

the-pump concept that motorists are already used to, OMFC requires no new actions and imposes no additional burdens on motorists. Unlike most other VMT fee proposals, under the OMFC, motorists are not even required to pay a monthly bill. Furthermore, the on-vehicle technology did not require any user interaction. This system did prevent motorists from being able to access their driving and payment histories, however, which also limits auditability.

The only other problem with the concept, as demonstrated in the study, is that it does not allow fixed cash prepayments because the amount of the mileage fee is not known until after the fuel is pumped. In a statewide implementation, the system's software could be changed so that the fee is calculated immediately when the vehicle establishes a connection with the pump instead of after the fuel has been pumped.

User-Friendliness score: 4

Criterion #4: Minimal Evasion and Fraud Potential

The pay-at-the-pump model eliminates many evasion and fraud concerns since refueling a vehicle requires payment of the mileage fee. As the study's final report succinctly states, "No payment, no gas."[49]

Another protection against evasion is the default to the gas tax in the event that a motorist switches off or disables the OBU. Nevertheless, drivers of highly fuel-efficient vehicles may have a stronger incentive to disable the OBU and pay the gas tax since such drivers are likely to pay more in mileage fees than gas taxes. The OMFC researchers did not directly address evasion

[49] Ibid., p. 7.

and fraud prevention during the pilot study and concede that "more research and development must occur to ensure the on-vehicle devices are tamper proof."[50]

Minimal Evasion and Fraud Potential score: 4

Criteria #5: Cost-Effectiveness

Startup and capital costs for the OMFC pilot study were quite high, primarily because most of the devices and technologies were prototypes. Total costs for the OBU, including development, manufacturing, and installation costs, were approximately $600 per unit. ODOT did note that as technology develops and units are mass produced in a full-scale implementation, per unit costs are likely to fall dramatically. In total, ODOT estimates that system capital costs for a statewide implementation in Oregon would cost approximately $32 million.[51]

One of the key questions under this system is who will bear the costs of implementation. For the pilot study, ODOT paid for the replacement of fuel pumps at the two participating gas stations with pumps that were equipped with the technology to operate the OMFC system. In a statewide implementation, however, this would not be feasible. One reason is that it would cost too much. Replacing only a few pumps cost Oregon $78,000. Another reason is that gas stations each have their own proprietary point-of-sale (POS) systems that they would not allow to be replaced with a government-issued system.

In a full-scale implementation, ODOT recommends that, rather than mandating a specific POS system, the government should establish basic specifications that proprietary POS systems must meet. While this would avoid a government takeover of POS systems, it would nevertheless

[50] Ibid., p. 26.
[51] Ibid.

require gas stations to alter their existing POS systems. ODOT concedes that "[t]here are many different POS software systems in use by service stations, each of which will require custom modifications to integrate with the Oregon mileage fee."[52]

The pilot study's final report estimates that service station capital costs associated with modifications could exceed $30 million.[53] The report leaves it to the state legislature to decide if the costs should be borne by the private sector or by taxpayers, but it is clear that under this concept the private sector could face potentially significant burdens and costs.

Because the OMFC relies on existing pay-at-the-pump and gas tax collection models rather than creating a new central payment billing system, administrative costs might be similar to the gas tax. Enforcement and auditing costs will depend largely on how much data are collected and stored. If under a statewide implementation privacy is maximized and relatively little data are gathered and saved, enforcement and auditing costs will be low. If more auditability is desired and therefore more data are necessary, auditing and enforcement costs will necessarily increase.

Overall, ODOT estimates that the OMFC would increase the mileage fee rate by less than two percent if implemented statewide in Oregon.[54] However, a major flaw in the OMFC that is not accounted for in ODOT's cost estimates is that the system, as designed for the pilot study, does not apply to electric and alternative fuel vehicles since they don't utilize traditional gas pumps. The most obvious solution is to install readers similar to those installed on gas pumps at electric and alternative-fuel charging stations. However, such technology would require

[52] Ibid., p. 30.
[53] Ibid., p. 31.
[54] Ibid., p. 64.

additional development and increase system costs. ODOT acknowledges this problem but does not factor it into their cost estimates.[55]

Cost-Effectiveness score: 2

Criterion #6: System Flexibility

Although it wasn't demonstrated in the pilot study, ODOT assures that the OMFC can readily accommodate variable pricing, including congestion pricing, in a statewide implementation. The system can also be adapted to accommodate county- and city-specific pricing to ensure that each jurisdiction receives its fair share of revenues.

Beyond variable pricing, however, the system's flexibility is limited by the relatively simple, government-designed OBU, which doesn't allow user interaction, cannot support added features or applications, and virtually eliminates opportunities for private sector innovation. Overall, though, this system offers enough flexibility for policymakers to who wish only to use a VMT system for road pricing and no other ancillary objectives.

Flexibility score: 3

Final evaluation:

The OMFC demonstrated that a VMT fee can be integrated with the gas tax and utilize existing payment and collection systems. This should help to keep both startup and operations costs relatively low. The system's primary strengths are its simplicity and familiarity, which will make the transition to a VMT fee more palatable.

[55] Ibid., pp. 65-66.

However, the system as designed in the pilot study has glaring weaknesses, such as technological reliability issues, the lack of flexibility, and its incompatibility with electric and alternative-fuel vehicles. One of the primary reasons for implementing a VMT fee is to ensure that drivers of those vehicles pay for their road use. This problem must be resolved before the OMFC can be a viable option. Another potential challenge with this system is the question of who will bear the costs of replacing or modifying fuel pumps.

Proposal #4: Oregon's Road Usage Charge[56]

Oregon undertook its second VMT pilot study, known as the Road Usage Charge (RUC) Pilot Program, in 2012. This study ran between November 2012 and March 2013 and included 88 drivers from Oregon, Nevada, and Washington. The RUC was designed to address the problems with the Oregon Mileage Fee Concept – specifically technological unreliability, inflexibility, and the fact that electric and alternative-fuel vehicles were not included in OMFC – and to provide Oregon with a viable VMT concept for statewide implementation.

The hallmark of the RUC is its reliance on an open system architecture whereby the government establishes standards for the system's core functions – such as the mileage fee rate and mileage reporting options – and then allows the private sector to develop and market technologies that meet those standards and also offer additional features. This enables motorists to choose from a variety of devices and charge plans across a variety of account management providers.

[56] All information and data in this section was obtained from James M. Whitty, "Road Usage Charge Pilot Program 2013 & Per-Mile Charge Policy in Oregon," Oregon Department of Transportation, February 2014, http://www.oregon.gov/ODOT/HWY/RUFPP/docs/RUCPP%20Final%20Report%20-%20May%202014.pdf.

In the RUC pilot study, ODOT established four primary VMT fee options. The "basic" option consisted of a simple mileage counting and reporting device that did not have a GPS receiver. Without the GPS receiver, there was no way to distinguish between in-state and out-of-state miles so participants that chose this option paid for all miles traveled. The "advanced" option included a GPS device so that drivers were charged only for in-state miles. A third option allowed motorists to toggle between GPS monitoring and no GPS monitoring as they pleased by simply turning the GPS feature on and off. The final option involved no in-vehicle technology and required drivers to pay a flat monthly fee, which ODOT calculated based on an assumed maximum number of miles driven per month, as well as the gas tax. This option allowed drivers to avoid having to install mileage reporting devices in their vehicles if they so chose, but it was generally costlier because they still had to pay the gas tax.

Participants in the study ultimately were allowed to choose from five different plan options: ODOT administered a basic plan and the flat fee plan while the private firm offered a basic, an advanced, and a hybrid plan. However, in a real-world implementation, ODOT envisions many more plans being offered by a number of different providers. As stated in the pilot study's final report, "ODOT expects private vendors would use a per-mile charge system as a platform for marketing other products and services such as pay-as-you-drive insurance, tolling, and concierge—or perhaps these other services would serve as a platform for marketing the per mile charge."[57] For example, cell phone and wireless communications providers, cable television providers, and auto insurance companies could offer VMT plans and integrate mileage fees into customers' regular monthly bills.

[57] Ibid., p. 27.

The Road Usage Charge was demonstrated successfully enough that it was enacted into law by the Oregon state legislature in July 2013. Implementation began in July 2015 with 5,000 volunteers at a charge rate of 1.5 cents per mile. The state expects to eventually make the system mandatory and hopes it will serve as a model for other states to utilize and ultimately create an integrated VMT system nationwide.

Criterion #1: Privacy Protection

Under this system, drivers are essentially allowed to decide how much personal data they share and with whom they share it, depending on the plan they choose. In the pilot study, three plans – the two basic plans and the flat fee plan – ensured almost complete privacy protection because there was no GPS monitoring and little or no travel data were shared with the government. Moreover, the two plans in the study that did involve GPS monitoring, the advanced and hybrid plans, were both administered by a private firm, not the government.

In a full implementation scenario much will depend on how the system is designed, including the basic requirements established by the government and the kinds of plans offered. It will be incumbent upon the administering government to ensure that adequate privacy protections exist within all government-managed plans and that sufficient legal and procedural protections are in place to limit government access to information collected by private firms.

Privacy Protection score: 4

Criterion #2: Technological Reliability

The technology used in the pilot study performed very well. ODOT tested and approved all private sector technologies used in the pilot study to ensure they met the basic system standards and functioned properly. According to the final report, “Mileage reporting device

accuracy was measured during acceptance testing and shown to be 97-98% accurate when compared to mileage measured by the vehicle's odometer."[58] Additionally, the researchers reported no lost transactions and no inaccurate billing.

It should be noted, however, that the devices used in the study were relatively simple and did not include any special features or perform complex operations like congestion pricing. In a full-scale implementation, the government should establish an efficient approval process to ensure that all devices meet the established standards and function properly.

Due to the limited nature of the technology used in the pilot study and the wide range of possible technologies used in the future, I do not assign a score here.

Technological Reliability score: N/A

Criterion #3: User-Friendliness

Even though the options offered in the pilot study were relatively limited, they nevertheless provided participants with an acceptable range of technological and plan choices to meet their personal needs and preferences. Drivers could opt for more advanced GPS technology or use no technology at all. Furthermore, by involving the private sector in account management the system allows motorists to interact with familiar entities with whom they likely already share their personal information instead of requiring all data to be submitted to and managed by the government.

Again, much will depend on the specific system design and the range of available devices and plans, but as long as the private sector is given sufficient flexibility in a full-scale

[58] Ibid., p. 25.

implementation, this system should provide plenty of user-friendly options for motorists. A drawback to this kind of open system is the added complexity motorists will face as a result of having to choose between many different plans and technologies, but private providers and the government could provide guidance and technical support

User-Friendliness score: 4

Criterion #4: Minimal Evasion and Fraud Potential

In the pilot study, ODOT had authority to audit motorists and the private vendors to ensure that charges were being assessed accurately and that fees were being remitted appropriately to the government. ODOT also had authority to impose penalties for non-payment, tampering, and false reporting.

For their part, the private vendors in the study employed a number of measures to prevent tampering, including applying tamper-evident tape to devices, performing regular error checks in their software, and recording when devices were installed and removed from the vehicle. One major advantage of involving the private sector in the administration and operation of the system is that they likely already have strong tampering and evasion prevention methods and can work with the government to prevent such activities. The private vendors in the study expressed confidence that this system would very difficult to evade.[59]

Minimal Evasion and Fraud Potential score: 4

Criterion #5: Cost-Effectiveness

[59] Ibid., p. 25.

ODOT expects that utilizing the private sector and taking advantage of market efficiencies will significantly reduce system startup and capital costs. Moreover, because participating businesses are likely to benefit from the system, ODOT believes that "many of the costs of system implementation and operation would be borne by industry."[60]

ODOT estimates that initial administrative and operations costs could be as high as 20 to 50 percent of total revenues for 10,000 vehicles, but those costs are expected to fall sharply as participation increases. According to ODOT:

> As the number of participants grows and the market for value-added services expands, the cost to government of collecting per mile charges will decline substantially, as the majority of costs are built in to other service offerings. ODOT estimates when the number of road usage charge payers reaches one million, operating costs will drop to below five percent of gross revenues per annum.[61]

Comparatively, this proposal is the most cost-effective of all the proposals examined in this paper precisely because it harnesses to the greatest degree the private sector and market forces. However, it is still not as cost-effective as the gas tax.

Cost-Effectiveness score: 3

Criterion #6: System Flexibility

Designed specifically with flexibility in mind, this system is also the most flexible of all the proposals discussed in this paper. Virtually any technology can be used, the system is capable of addressing a wide range of policy objectives and supporting added features, and it is scalable

[60] Ibid., p. 27.
[61] Ibid.

from one state to multiple states and potentially could be implemented nationwide. While the pilot study did not demonstrate the system's flexibility, Oregon's RUC clearly provides a strong framework for a viable VMT fee system that can be adapted to meet future challenges.

System Flexibility score: 4

Final Evaluation:

Although the success of a system modeled after the Oregon RUC will ultimately be determined by the system's specific design, it is clear that the RUC offers the most promising path forward for implementing a VMT fee system and eventually replacing the gas tax. The administering government would be able to tailor the system to the unique circumstances that exist within its jurisdiction and by relying mostly on the private sector to market devices and administer plans, motorists would be able to choose the technologies and plans that best suit their needs.

5. DISCUSSION AND ANALYSIS

The following table summarizes the scores of the four proposals for each criteria:

	Privacy Protection	Technological Reliability	User-Friendliness	Fraud/Evasion Potential	Cost-Effectiveness	System Flexibility	Total Score
University of Iowa Mileage-Based User Charge	4	3	2	N/A	N/A	2	11*
Minnesota Road User Fee	4	1	2	3	3	4	17
Oregon Mileage Fee	3	2	4	4	2	3	18
Oregon Road Usage Charge	4	N/A	4	4	3	4	19*

Note: an asterisk (*) in the Total Score column indicates that the row total is incomplete because some individual scores are listed as N/A.

Perhaps unsurprisingly, all of the proposals performed well on the privacy protection criterion, as this is considered the most controversial aspect of a GPS-based VMT fee and thus all four of the proposals made privacy protection a top priority. The pilot studies demonstrated a number of ways to protect privacy sufficiently in a large-scale implementation. Whether this will be enough evidence to convince the general public that their privacy is secure remains to be seen. Ultimately, it will be up to administering governments to decide the best ways to educate the public about VMT fees and convince them that their privacy is adequately protected.

From the technological reliability scores, it is clear that more development is needed prior to a large-scale VMT fee implementation. Two of the proposals – the Minnesota Road User Fee and the Oregon Mileage Fee – were not reliable enough to recommend for an immediate real-world implementation. Currently, the most reliable technology available for immediate implementation is the simple on-board unit concept used in the University of Iowa study. However, it must be recognized that because of the time and funding constraints inherent in all of the pilot studies reviewed, the researchers were not able to develop or utilize their ideal technologies. In a real-world implementation, far more resources will be available to develop more reliable technologies tailored to meet specific policy goals. Given enough time and funding, all of the technologies evaluated herein could eventually be viable options in the long run.

The proposals' user-friendliness scores also were mixed, with the two Oregon proposals performing very well and the University of Iowa and Minnesota proposals needing significant improvements. The University of Iowa pilot study demonstrated the necessity of selecting an easy-to-install on-board device in a large-scale VMT fee implementation. An OBU that requires professional installation or is difficult or time-consuming for drivers to install themselves isn't a

viable option for real-world implementation. Similarly, the Minnesota Road User Fee's required regular odometer checks to ensure accurate mileage counting and fee calculation would likely prove too burdensome and costly for many drivers.

Another top priority for most VMT fee proposals is to ensure that drivers cannot easily evade the fees. The primary purpose of a VMT fee, after all, is to provide a steady and reliable revenue stream for road funding and if drivers are able to evade the charges easily, it will undermine the fee's effectiveness severely. The three proposals for which sufficient information was available to provide a score all performed well on this metric, or at least spelled out a viable plan to prevent fraud and evasion in a real-world implementation. Much of the fraud and evasion prevention efforts will need to be handled by the federal or state legislatures prior to implementation by enacting criminal penalties for tampering with VMT technologies or otherwise attempting to evade the fees.

Assigning cost-effectiveness scores was difficult because cost information for the proposals was relatively incomplete. This is understandable since, as already noted, the pilot studies were limited in their implementation and operations and therefore were not representative of a full-scale implementation. As such, the cost estimates that were available were only rough and may not accurately represent the actual costs of implementing and operating a VMT system. Generally, however, the more a VMT fee system relies on the private sector to develop technologies and operate the system, the more cost-effective the system is likely to be. But governments must be careful not to burden the private sector unduly, as the Oregon Mileage Fee concept runs the risk of doing.

System flexibility varied among the four proposals. Two of the proposals – the Minnesota Road User Fee and the Oregon Road User Charge – prioritize flexibility and provide

governments with the ability to integrate a variety of policy objectives into the system. The Oregon Road User Charge is specifically designed to be scalable so that the system can eventually be expanded to a regional or national level. If VMT fees are implemented only at the state level, some states may not prioritize system flexibility as highly as others. For example, rural states may not feel the need to implement congestion pricing with their VMT system and may therefore opt for a simple technology like that used in the University of Iowa proposal. This may lead to interoperability issues among states that would have to be addressed on a regional or national level.

Each of the proposals examined here offer comparative advantages and disadvantages Governments may find one proposal more attractive than another depending on different contexts and circumstances. The University of Iowa Mileage-Based User Charge, with its simple design and minimal new technology, offers an ideal system for states to use to conduct preliminary pilot studies and experiment with the concept of a VMT fee to introduce drivers to an alternative system to the gas tax. Assuming that the device installation challenges can be resolved prior to a full-scale implementation, this concept may also be ideal for a statewide VMT fee if policymakers are not concerned about pursuing additional policy objectives other than levying road user fees. Additionally, states that are especially strapped for road funding may prefer this concept because it can be implemented relatively quickly, likely over the span of just a few years, because of its simplicity. This concept is probably not an ideal option for a national VMT fee, however, because of the political challenges associated with the federal government mandating a single on-board device for the entire country.

Until reliable cellphone GPS technologies are available, the Minnesota Road User Fee concept isn't a viable alternative to the gas tax. Furthermore, even when the technology becomes

sufficiently reliable, the concept may not be feasible if, as in the Minnesota pilot study, too many drivers object to having to remember to bring and plug in their cellphones every time they drive. As such, a cellphone-based VMT fee system is probably not practical as a standalone system, regardless of technological reliability. It would work best if it was included as one option in a broader system, such as the Oregon Road User Charge concept that allows drivers to choose from a variety of technologies.

The pay-at-the-pump model used in the Oregon Mileage Fee concept would be ideal for a nationwide VMT fee because the federal government could establish uniform fuel pump technology and would have significantly more leverage than states to negotiate with major oil companies and gas stations to implement the new technologies nationwide. The problem with the federal government taking the lead in the VMT fee transition, however, is that the process would undoubtedly take years to complete because of the political difficulty of agreeing on a single system for the entire country and the possible pushback from oil companies and gas stations. As such, this concept may not be a viable short-term option and states and the federal government may need to look for other sources of road funding – possibly increase gas taxes – in the meantime.

The Oregon Road User Charge offers the most promising alternative to the gas tax because of its exceptionally flexibility. With this concept, states can continue to take the lead in designing, testing, and implementing VMT fees according to their own unique circumstances and policy preferences, all while ensuring interoperability with other states, as long as certain minimum system requirements are established. The federal government could assume responsibility for establishing these standards or states could work together, either regionally or nationally, to develop standards. The necessity of interstate coordination, coupled with the time it

will take the private sector to develop, and the government to approve, the technologies necessary to support this kind of VMT fee, may make this concept more viable in the intermediate- to long-term rather than the short-term, so states and the federal government may still need to find short-term funding solutions. But overall, the Oregon Road User Charge is the best VMT fee option among the four examined in this paper, regardless of the level of government at which a VMT fee is implemented.

6. RECOMMENDATIONS AND CONCLUSION

The time has come in the United States to begin transitioning from motor fuel taxes to a system of vehicle miles traveled fees. The technology is available and pilot studies have demonstrated that a VMT system can be implemented and administered efficiently and effectively. The most attractive option is the Oregon Road User Charge model, which offers a flexible, market-based concept that states can tailor to meet their own unique needs and policy goals. While the federal government could also use the Road User Charge model to implement a national VMT fee, the most sensible approach is to let states continue to experiment with and implement their own VMT fee systems. States should also begin working collaboratively ensure interoperability among state systems. Randal O'Toole, a transportation policy expert at the Cato Institute, has suggested that the American Association of State Highway and Transportation Officials (AASHTO) write uniform standards for states to follow when creating their own VMT fee systems.[62] This could eventually lead to an integrated nationwide system created and managed almost entirely by the states.

[62] O'Toole, "Ending Congestion," http://www.cato.org/publications/policy-analysis/ending-congestion-refinancing-highways, p. 14.

For their part, federal policymakers should start phasing out the federal gas tax and remitting most road funding and maintenance authority to the states. O'Toole suggests this could be done within 6 to 18 years, depending on how quickly the federal and state governments choose to transition to a VMT fee. O'Toole also proposes that the federal government encourage states to adopt VMT fees by offering states that are working towards implementing a VMT system a larger portion of federal gas tax revenues.[63]

Implementation likely will be a gradual process, with each state moving at its own pace. As such, a VMT fee will not solve the short-term road funding problems for the federal government or most state governments. Policymakers therefore will need to come up with intermediary solutions to deal with existing funding challenges until a VMT system is able to provide sufficient revenues. For example, states may need to consider raising their fuel taxes temporarily. This could be done in concert with the phasing out of the federal gas tax. As the federal tax is reduced, state taxes can be increased by a similar amount, thus giving the states more revenues but not increasing net gas taxes for drivers.

Another solution is for the federal government and the states to find other ways of funding non-highway-related projects that are currently funded with gas taxes. For the federal government, this would mean coming up with alternative funding mechanisms for its mass transit programs which are currently funded through the Highway Trust Fund. Similarly, as states adopt VMT fees they should require all revenues to be dedicated exclusively to funding highway- and road-related projects, thereby ensuring that VMT fees are a true user fee.

[63] Ibid., p. 15.

Such short-term challenges should not discourage policymakers from pursuing VMT fees as a replacement for the gas tax. The road to implementing a VMT system will not be easy but the long-term benefits for both motorists and government are worth it.